DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 472

RESULTS OF SPIRIT LEVELING IN SOUTH DAKOTA

1896 TO 1910, INCLUSIVE

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1911

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ILLUSTRATION.

GEOLOGICAL SURVEY BENCH MARKS.

A, Tablet used in cooperating States. The State name is inserted at *G*.
B and *D*, Copper temporary bench mark, consisting of a nail and copper washer.
A, *C*, and *E*, Tablets for stone or concrete structures.
F, Iron post used where there is no rock.

RESULTS OF SPIRIT LEVELING IN SOUTH DAKOTA, 1896 TO 1910, INCLUSIVE.

R. B. MARSHALL, Chief Geographer.

INTRODUCTION.

Scope of the work.—All results of spirit leveling in South Dakota previously published by the United States Geological Survey and all the results of later work are included in this report, rearranged by quadrangles. Elevations are based on heights of bench marks along precise level lines of the Coast and Geodetic Survey as adjusted in 1907, and on checked primary leveling of the Missouri River Commission.

Personnel.—The field work in the western part of the State from 1896 to 1906, inclusive, was done under the general direction of E. M. Douglas, geographer. That for the remainder of the State, previous to 1903, was under the general direction of J. H. Renshawe, geographer, and from 1903 to 1906, inclusive, under H. M. Wilson, geographer. Since 1907 the work has been under E. C. Barnard and Sledge Tatum, geographers, under the general direction of R. B. Marshall, chief geographer. The names of the various levelmen are given in the introduction to each list. The office work of computation, adjustment, and preparation of lists was done mainly by S. S. Gannett, geographer, and D. H. Baldwin, topographer, and since 1907 under the general direction of E. M. Douglas, geographer.

Classification.—No precise leveling has been done by the United States Geological Survey in this State.

For primary lines standard Y levels are used; lines are run in circuits or are closed on precise lines, with an allowable closing error in feet represented by $0.05\sqrt{D}$, in which D is the length of the circuit in miles, sufficient care being given to the work to maintain this standard. For circuit closures careful office adjustments are made, the small outstanding errors being distributed over the lines.

Bench marks.—The standard bench marks are of two forms. The first form is a circular bronze or aluminum tablet (*C* and *E*, Pl. I), 3½ inches in diameter and one-quarter inch thick, having a 3-inch stem, which is cemented in a drill hole in solid rock in the wall of some public building, a bridge abutment, or other substantial masonry structure. The second form (F, Pl. I), used where masonry or rock is not available, consists of a hollow wrought-iron post 3½ inches in outer diameter and 4 feet in length. The bottom is spread out to a width of 10 inches in order to give a firm bearing on the earth. A bronze or aluminum-bronze cap is riveted over the top of the post which is set about 3 feet in the ground. A third style of bench mark with abbreviated lettering (*B* and *D*, Pl. I) is used for unimportant points. This consists of a special copper nail 1¼ inches in length driven through a copper washer seven-eighths inch in diameter. The tablets as well as the caps on the iron posts are appropriately lettered, and cooperation by States is indicated by the addition of the State name (*G*, Pl. I).

The numbers stamped on the bench marks described in the following pages represent the elevations to the nearest foot as determined by the levelman. These numbers are stamped with three-sixteenths-inch steel dies on the tablets or post caps, to the left of the word "feet." The office adjustment of the notes and the reduction to mean sea level datum may so change some of the figures that the original markings are 1 or 2 feet in error. It is assumed that engineers and others who have occasion to use the bench-mark elevations will apply to the Director of the United States Geological Survey at Washington, D. C., for the adjusted values, and will use the markings as identification numbers only.

Datum.—All United States Geological Survey elevations are referred to mean sea level, which is the level that the sea would assume if the influence of winds and tides was eliminated. This level is not the elevation determined from the mean of the highest and the lowest tides, nor is it the half sum of the mean of all the high tides and the mean of all the low tides, which is called the half-tide level. *Mean sea level is the average height of the water, all stages of the tide being considered.* It is determined from observations made by means of tidal gages placed at stations where local conditions, such as long, narrow bays, rivers, and like features, will not affect the height of the water. To obtain even approximately correct results these observations must extend over at least one lunar month, and if accuracy is desired they must extend over several years. At ocean stations the half-tide level and the mean sea level usually differ but little. It is assumed that there is no difference between the mean sea level as determined from observations in the Atlantic Ocean, the Gulf of Mexico, or the Pacific Ocean.

The connection with tidal stations for bench marks in certain areas that lie at some distance from the sea coast is still uncertain, and this fact is indicated by the addition of a letter or word to the right of the word "DATUM" on tablets or posts. For such areas corrections for published results will be made from time to time as the precise-level lines of the United States Geological Survey or other Government organizations are extended.

Topographic maps.—Topographic maps of the following quadrangles wholly or partly in South Dakota have been published by the United States Geological Survey up to May 1, 1911. They may be obtained for 5 cents each or $3 a hundred, on application to the Director of the Survey at Washington, D. C.

Aberdeen.[1]
Aladdin (Wyoming-South Dakota-Montana).
Alexandria.
Belle Fourche.[2]
Byron.
Canton (South Dakota-Iowa).
Columbia 30′ (South Dakota-North Dakota).[3]
Columbia 15′.[3]
Conde.[1]
Deadwood.[4]
De Smet.
Edgemont (South Dakota-Nebraska).
Elk Point (South Dakota-Nebraska-Iowa).
Ellendale 30′ (South Dakota-North Dakota).[5]
Ellendale 15′ (North Dakota-South Dakota).[5]
Harney Peak.
Hecla (South Dakota-North Dakota).[3]
Hermosa.
Huron.
Mitchell.
Newcastle (Wyoming-South Dakota).
Northville.
Oelrichs (South Dakota-Nebraska).
Olivet.
Parker.
Rapid.
Redfield.
Redwater.[2]
St. Onge.[2]
Savo (South Dakota-North Dakota).[3]
Spearfish.[4]
Sturgis.[4]
Sundance (Wyoming-South Dakota).
Vale.

PRIMARY LEVELING.

Canton, Elk Point, Olivet, and Parker Quadrangles.

BONHOMME, CLAY, HUTCHINSON, LINCOLN, TURNER, UNION, AND YANKTON COUNTIES.

The elevations in the following list were determined by primary leveling extended from bench marks of the Missouri River Commission and the Coast and Geodetic Survey, and accord with the 1907 adjustment. A correction of +0.755 foot has been applied to the values published in part 3 of the Report of the Chief of Engineers United States Army, for 1894, at and west of Elk Point, a junction point with a precise level line of the Coast and Geodetic Survey, crossing the Elk Point and Canton quadrangles along the Chicago, Milwaukee & St. Paul Railway.

[1] Conde sheet, on scale of 1 : 62,500, has been reduced and forms part of Aberdeen sheet, on a scale of 1 : 125,000.

[2] Redwater and St. Onge sheets, on scale of 1 : 62,500, have been reduced and form parts of Belle Fourche sheet, on scale of 1 : 125,000.

[3] Columbia 15′ Hecla, and Savo sheets, on scale of 1 : 62,500, have been reduced and form parts of Columbia 30′ sheet on scale of 1 : 125,000.

[4] Spearfish and Sturgis sheets, on scale of 1 : 62,500, have been reduced and form parts of Deadwood sheet, on scale of 1 : 125,000.

[5] Ellendale 15′ sheet, on scale of 1 : 62,500, has been reduced and forms part of Ellendale 30′ sheet, on scale of 1 : 125,000.

The leveling was done in the Canton, Olivet, and Parker quadrangles by Alfred Tyler in 1896, and in the Elk Point quadrangle by D. C. Wray in 1898.

The Iowa elevations in the Canton and Elk Point quadrangles and the Nebraska elevation in the Elk Point quadrangle are given in the spirit leveling bulletins for those States.

CANTON QUADRANGLE.

Centerville east along Chicago & Northwestern Ry. to line between R. 52 W. and R. 51 W., thence south to line between Tps. 95 and 96 N., east to line of Rs. 48 and 49 W., north to line of Tps. 96 and 97 W., west to line of Rs. 51 and 52 W., and southwest to Centerville.

	Feet.
T. 95 N., R. 51 W., northwest corner of sec. 6; iron post stamped "YNKTN 1254"	1, 254. 341
T. 95 N., R. 50 W., northwest corner of sec. 6; iron post stamped "YNKTN 1422"	1. 422. 576
T. 95 N., R. 49 W., northwest corner of sec. 6; iron post stamped "YNKTN 1390"	1, 391. 018
T. 95 N., R. 48 W., northwest corner of sec. 6; iron post stamped "YNKTN 1438"	1, 438. 373
T. 96 N., R. 48 W., northwest corner of sec. 6; iron post stamped "YNKTN 1485"	1, 486. 110
T. 96 N., R. 49 W., northwest corner of sec. 6; iron post stamped "YNKTN 1538"	1, 538. 474
T. 96 N., R. 50 W., northwest corner of sec. 6; iron post stamped "YNKTN 1372"	1, 372. 981
T. 96 N., R. 51 W., northwest corner of sec. 6; iron post stamped "YNKTN 1217"	1, 217. 483

Sec. 18, T. 97 N., R. 52 W., northeast to Davis, thence east to line of Rs. 48 and 49, thence northwest to sec. 3, T. 98 N., R. 49 W.

T. 97 N., R. 51 W., northwest corner of sec. 6; iron post stamped "YNKTN 1273"	1, 273. 726
T. 97 N., R. 50 W., northwest corner of sec. 6; iron post stamped "YNKTN 1299"	1, 300. 050
T. 97 N., R. 49 W., northwest corner of sec. 6; iron post stamped "YNKTN 1337"	1, 337. 759
T. 97 N., R. 48 W., northwest corner of sec. 6; iron post stamped "YNKTN 1274"	1, 274. 951

Parker southeast along Chicago, Milwaukee & St. Paul Ry. and highway to corner of Tps. 98 and 99 N., Rs. 51 and 52 W., thence east along township line to line of Rs. 48 and 49 W., thence northwest to sec. 7, T. 100 N., R. 49 W., thence west and south to sec. 15, T. 100 N., R. 53 W. (portion of line).

T. 98 N., R. 51 W., northwest corner of sec. 6; iron post stamped "YNKTN 1335"	1, 335. 722
T. 98 N., R. 50 W., northwest corner of sec. 6; iron post stamped "YNKTN 1349"	1, 349. 833
T. 98 N., R. 49 W., northwest corner of sec. 6; iron post stamped "YNKTN 1372"	1, 372. 722
T. 98 N., R. 48 W., northwest corner of sec. 6; iron post stamped "YNKTN 1329"	1, 330. 511

	Feet.
T. 100 N., R. 49 W., northwest corner of sec. 7; iron post stamped "YNKTN 1484"	1,484.804
T. 100 N., R. 50 W., northwest corner of sec. 7; iron post stamped "YNKTN 1504"	1,505.750
T. 100 N., R. 51 W., northwest corner of sec. 7; iron post stamped "YNKTN 1534"	1,535.090

Sec. 30, T. 99 N., R. 51 W., north along range line to line between Tps. 99 and 100 N., thence east to line of Rs. 49 and 50 W., thence southeast to sec. 34, T. 99 N., R. 49 W.

T. 99 N., R. 51 W., northwest corner of sec. 6; iron post stamped "YNKTN 1448"	1,448.967
T. 99 N., R. 50 W., northwest corner of sec. 6; iron post stamped "YNKTN 1461"	1,462.306
T. 99 N., R. 49 W., northwest corner of sec. 6; iron post stamped "YNKTN 1419"	1,420.049

PARKER QUADRANGLE.

Yankton northeast along Chicago & Northwestern Ry. to Centerville, thence northwest to Parker.

Wakonda, in front of town hall, sec. 33, T 95 N., R. 53 W.; iron post stamped "YNKTN 1390"	1,391.191
Hurley, in center of park, sec. 27, T. 98 N., R. 53 W.; iron post stamped "YNKTN 1293"	1,293.841
T. 98 N., R. 53 W., northeast corner of sec. 4; iron post stamped "YNKTN 1300"	1,300.719
Parker, in foundation of courthouse, sec. 17, T. 99 N., R. 53 W., bronze tablet stamped "1371 YNKTN"	1,373.361

Hurley south and west to sec. 15, T. 97 N., R. 54 W., thence east and south to T. 95 N., R. 53 W.

T. 97 N., R. 53 W., northeast corner of sec. 20; iron post stamped "YNKTN 1281"	1,282.116
T. 97 N., R. 54 W., northeast corner of sec. 21; iron post stamped "YNKTN 1360"	1,361.247
T. 96 N., R. 54 W., northeast corner of sec. 1; iron post stamped "YNKTN 1382"	1,383.940
Irene, near township corners, sec. 1, T. 95 N., R. 54 W.; iron post stamped "YNKTN 1371"	1,372.596
T. 95 N., R. 53 W., northeast corner of sec. 4; iron post stamped "YNKTN 1323"	1,324.282

Parker along Chicago, Milwaukee & St. Paul Ry. northwest to Marion, thence southwest to T. 98 N., R. 57 W.

Freeman, southeast corner of Windmill Square, sec. 35, T. 99 N., R. 56 W.; iron post stamped "YNKTN 1514"	1,515.203

Parker northeast to sec. 15, T. 100 N., R. 53 W., thence north and west to sec. 10, T. 100 N., R. 54 W., thence south to sec. 15, T. 97 N., R. 54 W.

T. 100 N., R. 53 W., northeast corner of sec. 21; iron post stamped "YNKTN 1402"	1,403.865
T. 100 N., R. 54 W., northeast corner of sec. 12; iron post stamped "YNKTN 1358"	1,360.098

	Feet.
T. 99 N., R. 54 W., northeast corner of sec. 21; iron post stamped "YNKTN 1454"	1,455.998
T. 98 N., R. 54 W., northeast corner of sec. 4; iron post stamped "YNKTN 1412"	1,414.121
T. 98 N., R. 54 W., northeast corner of sec. 21; iron post stamped "YNKTN 1346"	1,347.966
T. 97 N., R. 54 W., northeast corner of sec. 4; iron post stamped "YNKTN 1302"	1,303.384

Marion west and north to sec. 12, T. 100 N., R. 55 W., thence northwest to sec. 9, thence south to sec. 15, T. 97 N., R. 55 W., thence east to sec. 15, T. 97 N., R. 54 W.

T. 99 N., R. 55 W., northeast corner of sec. 4; iron post stamped "YNKTN 1444"	1,445.838
T. 100 N., R. 55 W., northeast corner of sec. 9; iron post stamped "YNKTN 1397"	1,398.725
T. 99 N., R. 55 W., northeast corner of sec. 21; iron post stamped "YNKTN 1474"	1,475.082
T. 98 N., R. 55 W., northeast corner of sec. 4; iron post stamped "YNKTN 1525"	1,526.320
T. 98 N., R. 55 W., northeast corner of sec. 21; iron post stamped "YNKTN 1434"	1,435.248
T. 97 N., R. 55 W., northeast corner of sec. 4; iron post stamped "YNKTN 1615"	1,616.119
T. 97 N., R. 55 W., northeast corner of sec. 21; iron post stamped "YNKTN 1683"	1,684.282

Sec. 15, T. 97 N., R. 55 W., south to sec. 30, T. 94 N., R. 54 W.

T. 96 N., R. 56 W., northeast corner of sec. 1; iron post stamped "YNKTN 1456"	1,457.204
T. 95 N., R. 55 W., northwest corner of sec. 6; iron post stamped "YNKTN 1311"	1,312.042
T. 95 N., R. 55 W., northeast corner of sec. 1; iron post stamped "YNKTN 1481"	1,482.330

Sec. 13, T. 98 N., R. 57 W., east 3 miles, thence north and west to sec. 12, T. 100 N., R. 57 W.

T. 98 N., R. 56 W., northeast corner of sec. 21; iron post stamped "YNKTN 1599"	1,600.826
T. 99 N., R. 56 W., northeast corner of sec. 4; iron post stamped "YNKTN 1445"	1,446.897

OLIVET QUADRANGLE.

Yankton along Chicago, Milwaukee & St. Paul Ry. northwest to Scotland, thence northeast to sec. 24, T. 98 N., R. 57 W.

Menno, crossroads, near mill; iron post stamped "YNKTN 1327"	1,328.414
T. 98 N., R. 57 W., northeast corner of sec. 24; iron post stamped "YNKTN 1403"	1,404.659

Sec. 9, T. 97 N., R. 57 W., south 5 miles, thence east to corner of Tps. 96 and 97 N., Rs. 55 and 56 W.

T. 96 N., R. 57 W., northeast corner of sec. 4; iron post stamped "YNKTN 1290"	1,291.764

	Feet.
T. 96 N., R. 57 W., northeast corner of sec. 1; iron post stamped "YNKTN 1307"	1,308.675

Sec. 36, T. 95 N., R. 57 W., north to sec. 1, thence west along township line to line between Rs. 60 and 61 W., thence north 6 miles, thence east along township line, and southeast to Scotland.

T. 95 N., R. 57 W., northeast corner of sec. 1; iron post stamped "YNKTN 1442"	1,443.301
T. 95 N., R. 58 W., northeast corner of sec. 1; iron post stamped "YNKTN 1338"	1,339.182
T. 95 N., R. 59 W., northeast corner of sec. 1; iron post stamped "YNKTN 1399"	1,399.780
T 95 N., R. 60 W., northeast corner of sec. 1; iron post stamped "YNKTN 1526"	1,527.195
T. 95 N., R. 61 W., northeast corner of sec. 1; iron post stamped "YNKTN 1596"	1,597.060
T. 96 N., R. 61 W., northeast corner of sec. 1; iron post stamped "YNKTN 1584"	1,585.152
T. 96 N., R. 60 W., northeast corner of sec. 1; iron post stamped "YNKTN 1446"	1,446.876
T. 96 N., R. 59 W., northeast corner of sec. 1; iron post stamped "YNKTN 1355"	1,356.441

Sec. 24, T. 97 N., R. 58 W., northwest to sec. 1, thence west to sec. 6, thence south to corner of Tps. 96 and 97 N., Rs. 58 and 59 W.

Olivet, southwest corner of foundation of courthouse; bronze tablet stamped "YNKTN 1221"	1,222.004

Corner of Tps. 96 and 97 N., Rs. 58 and 59 W., north along range line to Tps. 98 and 99 N., thence west along township line to Rs. 59 and 60 W., thence north to line of secs. 1-12, T. 100, R. 60 W., thence west 6 miles, thence south to corner of Tps. 97 and 98 N., Rs. 60 and 61 W., thence east to corner of Tps. 97 and 98 N., Rs. 58 and 59 W.

T. 97 N., R. 59 W., northeast corner of sec. 1; iron post stamped "YNKTN 1281"	1,281.956
T. 98 N., R. 59 W., northeast corner of sec. 1; iron post stamped "YNKTN 1312"	1,313.548
T. 98 N., R. 60 W., northeast corner of sec. 1; iron post stamped "YNKTN 1351"	1,352.174
T. 99 N., R. 60 W., northeast corner of sec. 1; iron post stamped "YNKTN 1316"	1,317.359
T. 100 N., R. 60 W., northeast corner of sec. 12; iron post stamped "YNKTN 1301"	1,301.825
T. 100 N., R. 61 W., northeast corner of sec. 12; iron post stamped "YNKTN 1371"	1,372.434
T. 99 N., R. 61 W., northeast corner of sec. 1; iron post stamped "YNKTN 1393"	1,394.011
T. 98 N., R. 61 W., northeast corner of sec. 1; iron post stamped "YNKTN 1433"	1,434.488
T. 97 N., R. 61 W., northeast corner of sec. 1; iron post stamped "YNKTN 1528"	1,529.414
T. 97 N., R. 60 W., northeast corner of sec. 1; iron post stamped "YNKTN 1396"	1,396.645

Sec. 9, T. 97 N., R. 57 W., north to sec. 21, T. 99 N., R. 57 W., thence west, north, and west to sec. 3, T. 99 N., R. 59 W.

	Feet.
T. 98 N., R. 57 W., northeast corner of sec. 21; iron post stamped "YNKTN 1351"	1,352.250
T. 98 N., R. 57 W., northeast corner of sec. 4; iron post stamped "YNKTN 1355"	1,356.542
T. 99 N., R. 57 W., northeast corner of sec. 21; iron post stamped "YNKTN 1366"	1,367.586
T. 99 N., R. 58 W., northeast corner of sec. 24; iron post stamped "YNKTN 1328"	1,328.732
T. 99 N., R. 58 W., northeast corner of sec. 4; iron post stamped "YNKTN 1330"	1,331.427
Milltown, at east end of James River Bridge; iron post stamped "YNKTN 1200"	1,200.821

Line of secs. 1 and 12, T. 100 N., R. 57 W., west to line between secs. 1 and 12, R. 59 W., thence south to Tps. 99 and 10 N.

T. 100 N., R. 57 W., northeast corner of sec. 12; iron post stamped "YNKTN 1410"	1,411.696
T. 100 N., R. 58 W., northeast corner of sec 12; iron post stamped "YNKTN 1349"	1,350.350
T. 100 N., R. 59 W., northeast corner of sec. 12; iron post stamped "YNKTN 1315"	1,316.432

ELK POINT QUADRANGLE.

Elk Point north to sec. 6, T. 94 N., R. 49 W., thence east to line between Rs. 48–49, thence south to line between Tps. 93 and 94, thence east to Chatsworth.

T. 91 N., R. 49 W., northwest corner of sec. 6; iron post stamped "YNKTN 1121"	1,122.176
T. 92 N., R. 49 W., northwest corner of sec. 6; iron post stamped "YNKTN 1293"	1,293.943
T. 93 N., R. 49 W., northwest corner of sec 6; iron post stamped "YNKTN 1347"	1,347.978
T. 94 N., R. 49 W., northwest corner of sec. 6; iron post stamped "YNKTN 1383"	1,383.261
T. 94 N., R. 48 W., near northwest corner of sec. 6; iron post stamped "YNKTN 1358"	1,358.425
T. 93 N., R. 48 W., near northwest corner of sec. 6; iron post stamped "YNKTN 1314"	1,314.845

Burbank north to sec. 6, T. 94 N., R. 50 W., thence west to line between Rs. 51 and 52, thence south to Vermillion.

T. 91 N., R. 50 W., northwest corner of sec. 6; iron post stamped "YNKTN 1137"	1,137.472
T. 92 N., R. 50 W., northwest corner of sec. 6; iron post stamped "YNKTN 1235"	1,236.018
T. 93 N., R. 50 W., northwest corner of sec. 6; iron post stamped "YNKTN 1274"	1,275.101
T. 94 N., R. 50 W., northwest corner of sec. 6; iron post stamped "YNKTN 1394"	1,394.340
T. 94 N., R. 51 W., northwest corner of sec. 6; iron post stamped "YNKTN 1228"	1,228.694

	Feet.
T. 93 N., R. 51 W., northwest corner of sec. 6; iron post stamped "YNKTN 1147"	1,148.056
T. 92 N., R. 51 W., northwest corner of sec. 6; iron post stamped "YNKTN 1183"	1,183.635

Elk Point south to sec. 6, T. 90 N., R. 49 W., thence east to line between Rs. 48 and 49 W., thence south to Jefferson.

T. 90 N., R. 49 W., northwest corner of sec. 6; iron post stamped "YNKTN 1128"	1,128.929
T. 90 N., R. 48 W., northwest corner of sec. 6; iron post stamped "YNKTN 1111"	1,111.685
Jefferson, northwest corner of school yard, at northwest side of walk, in stone set 4 feet underground and covered by a 3-inch pipe marked "U.S.B.M."; copper bolt (Missouri River Commission bench mark 358/3, re-covered by Coast and Geodetic Survey)	1,110.459

Deadwood, Edgemont, Harney Peak, Hermosa, Oelrichs, Rapid, and Sundance Quadrangles.

CUSTER, LAWRENCE, MEADE, AND PENNINGTON COUNTIES.

The elevations in the following list were originally based on a bronze tablet marked "4543," set in the city hall at Deadwood, and are stamped with the letters "DW." The elevations have been corrected to agree with the preliminary Coast and Geodetic Survey heights of bench marks near Edgemont.

The leveling was done between 1897 and 1900, by J. C. Barber, C. E. Worthington, and J. T. Stewart, with the exception of the line from Tilford to Deadwood and the leveling in the vicinity of Deadwood, which was done by L. F. Gottschalk.

DEADWOOD QUADRANGLE.

At Deadwood.

	Feet.
Deadwood, city hall, north entrance, in stone lintel on west side of door; bronze tablet stamped "DW 4543"	4,544.872
Deadwood, city hall, under window, northwest corner of building, 2 feet east of corner stone; top of water table	4,546.12
Deadwood, Chicago & Northwestern Ry. station; top of rail	4,532.9
Deadwood, north side of Deadwood Avenue, east side of Deadwood Creek, south face of southeast corner of Smith building, occupied in part by post office; bronze tablet stamped "DW 4535"	4,536.641
Deadwood, Chicago, Burlington & Quincy R. R. station, in front of ticket office; top of west rail	4,534.7

Deadwood via Chicago, Burlington & Quincy R. R. to Englewood.

Kirk, in front of Chicago, Burlington & Quincy R. R. station; top of rail	4,990.7
Kirk, 150 feet west of Chicago, Burlington & Quincy R. R. station, 45 feet southwest of railroad tracks, 15 feet north of wagon road, 30 feet southwest of telegraph pole, in top of north side quartzite rock 3 by 2 feet; copper bolt stamped "DW 4990"	4,991.284

	Feet.
Kirk, 2.25 miles south of, near stone quarry, east side of railroad tracks, 25 feet south of north end of cut, top of small projection, in niche on face of rock wall, 3 feet above rails; deep rock cut	5,324.92
Englewood, 1.25 miles north of, 60 feet south of wagon road crossing; cross on flat rock	5,423.11

Englewood to Rochford.

Englewood, 0.5 mile north of, 100 feet south of crossing of two branches of the Chicago, Burlington & Quincy R. R., 30 feet east of Burlington & Missouri River division track, in large rock 15 by 15 by 10 feet; bronze tablet in top of center stamped "DW 5537"	5,538.3
Englewood, in front of Chicago, Burlington & Quincy R. R. station; top of rail	5,590.4
Englewood, 0.5 mile south of, 35 feet east of track, 220 feet south of cattle guard, west side of center of ledge of light rock, just south of rock mound; cross on flat stone	5,674.15
Englewood, 1.5 miles south of, center of rock cut, 20 feet high on east side of track, 350 feet south of whistling post, 2.5 feet above tracks; cross on top of rock	5,840.83
Dumont, 0.8 mile north of, 60 feet west of wagon road crossing, 10 feet east of wagon-road running north and south; iron post stamped "DW 6178"	6,180.742
Dumont, opposite frog in switch, in front of section house; top of east rail	6,150.3
Bulldog ranch, 75 feet east of track, 50 feet northwest from wagon road, 15 feet southwest of post in mound of rock marked "U. S. L. M. 73," in top of small flat rock; bronze tablet stamped "DW 5863"	5,864.398
Nahant, 0.5 mile south of, 200 feet west of track, 30 feet southwest of wagon road, in northwest side of rock quarry, 14 feet above wagon road; copper bolt stamped "DW 5604"	5,605.621
Rochford, 1.6 miles northwest of, 2,000 feet north of junction of North and South Rapid creeks, 240 feet north of bridge 92, rock cut on east side of track, 100 feet from south end of cut; cross on rock near ground	5,383.08
Rochford, 1.2 miles west of, junction of North and South Rapid creeks, 200 feet west of track, 10 feet north of wagon road, 40 feet southeast of stream, on north side of rock 7 by 7 by 6 feet, 2.5 feet above ground; small cross	5,362.78
Rochford, west end of town, 30 feet north of junction of road along north bank of Rapid Creek with road from Hill City, in rock outcrop on point above 22 feet above track, 2 feet south of rock mound; copper bolt stamped "DW 5299"	5,300.408
Rochford, 300 feet west of railroad station, 10 feet north of track, 15 feet northeast of northeast corner of planking in road crossing, 1 foot from small mound of rock; projection in face of rock cut 1 foot above ground	5,229.04

Rochford to Redfern.

Rochford station, 3.5 miles southeast of, 100 feet northeast of bridge 79, 150 feet southeast of fork in wagon road, 25 feet northeast of road, in top of northwest one of two large slate rocks; copper bolt stamped "DW 4970"	4,971.438

	Feet.
Rochford station, 4.5 miles southeast of, 220 feet southeast of bridge 77, 8 feet southwest of track; projection in wall of rock cut 1.5 feet above tracks	4, 900. 42
Mystic, 3,500 feet northeast of, 300 feet south of signpost marked "Mystic," 40 feet west of track, 20 feet west of wagon road; wire nail in root of large spruce tree	4, 830. 14
Mystic, 1,500 feet west of sawmill near section house, 400 feet northeast of post office, 100 feet northwest of wagon road, 200 feet northwest of tracks, 7 feet above foot of rock outcrop on point, in east corner; copper bolt stamped "DW 4865"	4, 866. 725
Mystic, 4.5 miles southwest of, north end of divide between Castle and Slate Creeks, 3,500 feet northwest of bridge 68 over Slate Creek, 350 feet south of garden patch, 15 feet east of wagon road, 30 feet west of track, 50 feet southwest of "P. T." post, 30 feet north of end of waste dump; iron post stamped "DW 5514"	5, 515. 464
Redfern, at section house; top of road crossing	5, 632. 4

Sturgis to Whitewood.

Sturgis, about 0.5 mile northwest of Chicago & Northwestern Ry. station and 105 feet northeast of the first road crossing; iron post stamped "DW 3484"	3, 485. 868
Whitewood, 1 mile southeast of, 50 feet south of Sturgis and Whitewood wagon road, 70 feet southwest of road crossing, 0.25 mile east of northwest corner of sec. 27, T. 6 N., R. 4 E.; iron post stamped "DW 3590"	3, 591. 488

Deadwood along public road to Sturgis.

Deadwood, 2.25 miles east of, west of powder house and east of overhanging rock, just north of road crossing; spike in root on northeast side of 20-inch dead pine tree	4, 490. 37
Deadwood, 4.25 miles east of, south side of road about 1 mile east of Deadwood fair grounds, and about 75 feet east of wagon bridge over Peedee Creek; iron post on a flat bench stamped "DW 4454"	4, 455. 125
Deadwood, 5 miles east of, south side of road, opposite limestone ledge between two projecting ledges, southwest of projecting ledge with large anvil-shaped rock on top; spike on north side of 18-inch pine	4, 286. 11
Sturgis, 5.8 miles west of, at point where road makes a sharp turn to the east toward Boulder Park, after leaving the main divide on the north side; spike in root on north side of 15-inch burr oak	4, 146. 39
Sturgis, 3.8 miles west of, top of large limestone bowlder on south side of road, 460 feet east of the "Barroom" and 50 feet southwest of bridge across Bear Butte Creek; copper bolt stamped "DW 3814"	3, 815. 510
Sturgis, 1.25 miles west of, on south side of road and about 400 feet northeast of deserted log cabin on west side of mouth of canyon, at extreme north end of each ledge of Bear Butte Canyon; top of north end of stone	3, 577. 34
Sturgis, at first road crossing west of station, northeast of signboard, north of Chicago & Northwestern Ry. track; spike in root on southwest side of scrub oak	3, 484. 75

Deadwood via Centennial Park to Whitewood.

	Feet.
Deadwood, 4.5 miles north of, about 63 feet east of southeast corner of a large two-story dwelling known as the "Halfway House," just east of forks of road; iron post stamped "DW 4360"	4, 361. 325
Deadwood, 6.5 miles north of, 500 feet southeast of round stone water tank at Centennial Park, southeast of intersection of Deadwood-Spearfish road with old Spearfish-Whitewood road; iron post stamped "DW 4005"	4, 006. 023
Whitewood, 1 mile south of, 16 feet northeast of mile board, 18 feet east of Chicago & Northwestern Ry. track; iron post stamped "DW 3751"	3, 752. 831

Sturgis via Spring Creek public road north about 5 miles.

Sturgis, 5 miles northwest of, 400 feet southwest of large red barn with two ventilators on top, about 2,050 feet north of southwest corner of sec. 17, T. 6 N., R. 5 E., on east side of Spring Creek road; iron post stamped "DW 3308"	3, 309. 441

Runkel along Chicago, Burlington & Quincy R. R. to Englewood.

Runkel, 450 feet east of station, 15 feet north of track, just southwest of sawmill, on top of 10 by 15 by 8 foot limestone bowlder; copper bolt stamped "DW 4498"	4, 499. 713
Mowatts siding, 75 feet east of east switch, north of old log cabin, in limestone bowlder 10 feet north of track; copper bolt stamped "DW 4720"	4, 721. 840
Elk Creek station, in front of; top of rail	4, 842. 0
Elk Creek station, 0.5 mile west of, 30 feet south of railroad, 60 feet south of point where Galena and Greenwood road crosses track; iron post stamped "DW 4882"	4, 883. 374
Anthony station, at west end of; top of frog	4, 979. 0
Perry, 1.5 miles east of, 30 feet northeast of switch, at junction of Este branch Chicago, Burlington & Quincy R. R., on top of point of ledge; copper bolt stamped "DW 5269"	5, 270. 703
Portuguese siding, at signpost; top of rail	5, 342. 65
Perry, southeast corner of platform, at road crossing; top of rail	5, 401. 6
Brownsville, 650 feet southeast of station, 20 feet west of track, 60 feet northwest of road crossing, 80 feet southwest of second switch block from station; iron post stamped "DW 5496"	5, 497. 343
Brownsville, in front of station; top of rail	5, 503. 6
Woodville, 1.5 miles east of, 3.5 miles northwest of Brownsville, 20 feet east of Elk Creek–Kirk wagon road, 25 feet north of railroad; iron post stamped "DW 5743"	5, 744. 304
Woodville, switch block in front of station; top of rail	5, 935. 1
Woodville, 80 feet southeast of switch at station, 35 feet south of main track, in top of a large quartzite bowlder; copper bolt stamped "DW 5938"	5, 939. 633
Englewood, 0.5 mile north of, opposite Burlington & Missouri River R. R. transfer station; top of rail	5, 547. 5

Englewood via Spearfish branch of Chicago, Burlington & Quincy R. R. to Spearfish.

Englewood, 2 miles northwest of, 40 feet north of track and 40 feet west of Dumont–Lead City wagon road, about 75 feet northwest of bridge over railroad; iron post stamped "DW 5862"	5, 863. 285

	Feet.
Terry, in front of station; top of north rail of main line	6,165.3
Terry, 225 feet north of station, 30 feet east of north end of a short switch, on ledge about 2 feet above the surface of ground; bronze tablet stamped "DW 6165"	6,166.486
Portland, in front of station; top of rail	6,431.0
Portland, 600 feet northwest of station, at forks of wagon road 60 feet northeast of railroad (the only crossing between North and South Portland); iron post stamped "DW 6426"	6,427.297
Crownhill, in front of station; top of rail	6,154.8
Crownhill, 60 feet south of station, 40 feet west of track; iron post stamped "DW 6153"	6,154.274
Elmore, in front of water tank; top of rail	5,217.5
Elmore, 120 feet west of water tank, 80 feet south of section house, 40 feet south of track; iron post stamped "DW 5218"	5,219.816
Spearfish, 14 miles south of, 500 feet northwest of switch block at Savoy, in center of top of 12 by 12 by 20 foot limestone bowlder, between Spearfish River and railroad, 40 feet northeast of railroad; bronze tablet "DW 4954"	4,955.378
Maurice, opposite section house; top of rail	4,465.1
Spearfish, 8.8 miles south of, 40 feet west of railroad, 240 feet northeast of section house, 330 feet southwest of water tank, in top of limestone bowlder between section house and water tank; copper bolt stamped "DW 4470"	4,471.144
Spearfish, 3.5 miles south of, 460 feet south of Spearfish electric-light plant and 50 feet east of track, between track and Spearfish River; iron post stamped "DW 3892"	3,893.364
Spearfish, in front of station; top of rail	3,638.1
Spearfish, southwest corner of Star & Bullock stone building on corner of Sixth and I Streets, in water table; bronze tablet stamped "DW 3647"	3,648.655

Spearfish along public roads to Centennial Park.

Spearfish, 4.5 miles southeast of, 50 feet south of crossroads and 260 southwest of water tank, about 50 feet southeast of southeast corner of sec. 18, T. 6 N., R. 3 E.; iron post stamped "DW 3942"	3,943.396
Spearfish, 6 miles southeast of, 40 feet southeast of southeast corner stone of sec. 16, T. 6 N., R 3 E., 20 feet south of wagon road; iron post stamped "DW 3815"	3,816.388

Woodward ranch via Cold Springs to Bulldog ranch.

Woodward ranch, 1.25 miles south of, 1,000 feet southeast of Scott's unfinished cabin, 6 inches below top of limestone outcrop, 200 feet southwest of spring; witness tree 15 feet southeast, 10-inch pine; witness tree 125 feet west, 10-inch pine; copper bolt stamped "DW 6681"	6,682.638
Castle Creek, head of, in west side and 2 feet below top of limestone outcrop 10 by 10 feet, 150 feet northeast of intersection of Castle Creek, Cold Springs, and Newcastle roads; witness tree 150 feet north, 18-inch pine tree; witness tree 200 feet east, 18-inch pine tree; copper bolt stamped "DW 6536"	6,537.445

	Feet.
Cold Springs, 300 feet north of, in limestone ledge 15 feet higher than creek bed, 150 feet north of point where Cheyenne-Deadwood road crosses creek, 100 feet west of road, 200 feet west of road running south to head of Castle Creek; ledge shows out of ground 10 feet in length and 2 feet high; copper bolt stamped "DW 6417"	6,418.399
McQuaig road and Cheyenne-Deadwood road, 1 mile north of intersection of, east of road; nail in root of pine tree	6,567.1
McQuaig road and Cheyenne-Deadwood road, intersection of, 2 miles west of Colton ranch, in shelf of limestone cliff, 10 feet high and 15 feet long, on south bank dry creek channel, 100 feet south of the road intersection, 3 feet below top of cliff on the part farthest south and west; copper bolt stamped "DW 6464"	6,465.913
Colton ranch, 800 feet west of, 20 feet north of road; nail in side of big pine tree	6,300.05
Besant, 2 miles west of, on north edge of highway; nail in root of pine tree	6,591.36
Bulldog ranch, 2.25 miles west of, 300 feet south of dwelling at abandoned sawmill, 20 feet east of wire fence at road intersection; nail in root of spruce tree	6,064.09
Bulldog ranch, 0.7 mile west of; nail in root of balsam tree at edge of timber	5,964.92

Bulldog ranch, on Chicago, Burlington & Quincy R. R., east to Nasby.

Bulldog ranch, 1 mile east of, in middle of road; nail in root of large pine tree	6,008.02
Bulldog ranch, 3 miles east of, south edge of highway 150 feet east of log house; nail in root of large pine tree	5,817.58
Dayton ranch, 0.4 mile east of, ridge south side of highway, 50 feet north of fence; nail in root of large pine tree	5,730.01
Rassumussen ranch, 0.25 mile east of, 20 feet from gate; nail in root pine tree	5,493.35
Nasby, 200 feet north of dwelling, 50 feet northwest of road intersection; iron post stamped "DW 5456"	5,457.518

Nasby southeast to Merritt.

Peterson ranch, 150 feet east of dwelling, on west side of road; iron post stamped "DW 5322"	5,323.502
Peterson ranch, 1 mile southeast of, 20 feet west of road, 800 feet south of top of ridge; nail in root of 15-inch pine	5,394.66
Merritt, 0.8 mile west of, stone at fence corner northwest of intersection of Silver City and Merritt roads; point 1 inch west of piece of white quartz in northwest end of stone	5,135.34
Merritt, at post office, 60 feet northeast of ranch on north side of road; iron post stamped "DW 5059"	5,060.540

Chicago, Burlington & Quincy R. R. bridge 74, about 1.5 miles northeast of Mystic, to Silver City and Pactola.

Castle Creek, 150 feet west of junction with Rapid Creek, 35 feet north of small highway bridge over Rapid Creek, 40 feet east of cabin; wire nail in southeast side of 18-inch pine stump	4,771.92
Castle Creek, 4,500 feet southeast of mouth, 40 feet south of small highway bridge over Rapid Creek, 12 feet west of south end of high trestle bearing flume, 10 feet southeast of wagon road; point on west face of columnar rock 18 inches above ground	4,726.26

Silver City, 2.8 miles west of, 5 feet north of road up Rapid Creek, 30 feet west of junction with Merritt Road, southeast corner of high point of rock, on small shelf 2.5 feet above road; location marked by spruce 1 foot in diameter west 145 feet and three pine trees marked "U.S.G.S. B.M. W.T.," one 2.5 feet in diameter east 120 feet, one 15 inches in diameter northeast 100 feet, and one 1 foot in diameter north 65 feet; bronze tablet stamped "DW 4698" — Feet. 4,699.428

Silver City, 1.6 miles west of, 40 feet southwest of highway bridge over Rapid Creek, at mouth of deep gulch coming in from the southwest; spike in root west side of 18-inch spruce tree — 4,660.38

Silver City, 1,200 feet east of post office, 110 feet southwest of highway bridge over Rapid Creek, 15 feet southwest of junction of road down Nugget Gulch with road down Rapid Creek; iron post stamped "DW 4592" — 4,593.433

Silver City, 1.9 miles east of, at mouth of Jenny Gulch, 220 feet east of highway bridge over Rapid Creek, 40 feet northeast of highway bridge over ditch, 200 feet east of head gates; spike in north side of 15-inch pine tree — 4,547.48

Pactola, 1.8 miles west of, 15 feet southwest of road to Silver City, 350 feet northwest of junction with road running up Bear Gulch, 220 feet north of house, near two pine trees marked "U.S.G.S. B.M. W.T.," one 20 inches in diameter southeast 35 feet, one 2.5 feet in diameter west 25 feet; iron post stamped "DW 4518" — 4,519.371

Pactola northwest to Merritt.

Pactola, 1.2 miles northwest of, 50 feet southwest of road to Merritt, 80 feet east of plank fence, at top of steep hill; spike in west root of 15-inch pine tree — 4,742.58

Traft ranch, 900 feet southeast of, 150 feet from top of divide between Rapid and Deer creeks, 20 feet southwest of road from Pactola to Merritt; spike in root on north side of 15-inch pine tree — 4,886.48

Pactola, 3 miles northwest of, 0.25 mile northwest of Hughes ranch, 35 feet southwest of road from Pactola to Merritt, 190 feet northwest of fork in road; two witness trees marked "U.S.G.S. B.M. W.T.," 6 inches diameter northwest 200 feet; iron post stamped "DW 4934" — 4,935.545

Ireland ranch, 500 feet northwest of, 25 feet southwest of road from Pactola to Merritt; spike in root northwest side of 2.5 foot pine tree — 5,054.17

Merritt post office (Jones ranch), 3,000 feet southeast of, in fork of road from Pactola to Merritt, 8 feet below and 140 feet northwest of top of divide between Jim and Deer creeks; large wire spike in root southeast side of 13-inch pine tree — 5,197.18

Merritt east down Jim Creek.

Merritt, 0.8 mile northeast of, 4 feet south of road down Jim Creek, 350 feet east of fence; wire nail in west side of 20-inch pine tree — 4,997.45

Merritt, 2.5 miles northeast of, 25 feet south of wagon road down Jim Creek, 65 feet south of old cabin 330 feet east of fence; wire nail in root north side of 2.5-foot pine tree — 4,823.05

Merritt, 3.25 miles east of, 500 feet south of old sawmill, 30 feet north of road down Jim Creek, tree used as southwest gatepost in wire fence; spike in root south side — 4,745.65

	Feet.
Riley ranch (on Bogus Jim Creek), 0.25 mile northwest of, 8 feet southwest of timber road, in saddle on top of divide between Jim Creek and Bogus Jim Creek; spike in south side of 12-inch pine tree	4,776.02

Nemo via Greenwood to Nasby.

Nemo, 0.8 mile southeast of, 35 feet northeast of road down Boxelder Creek, 900 feet northeast of bridge over Boxelder Creek; spike in west root of 18-inch pine tree on rocky point	4,653.57
Nemo, 500 feet northwest of, 10 feet southwest of road to Greenwood on top of slight ridge; spike in root northwest side of 24-inch pine tree	4,706.12
Nemo, 3,500 feet northwest of, junction of road from Greenwood with road from Elk Creek; spike in root of 15-inch pine	4,740.17
Greenwood, 2 miles southeast of, 10 feet northeast of road to Nemo, at junction of county road from Elk Creek to Nemo; near three pine trees marked "U.S.G.S. B.M. W.T.," one 20 inches in diameter southeast 105 feet, one 20 inches in diameter northwest 35 feet, one 18 inches in diameter southwest 70 feet; iron post stamped "DW 4786"	4,787.188
Greenwood, 1 mile southeast of, top of divide between Greenwood and Nemo, 8 feet north of county road; spike in east root of 18-inch pine	4,997.11
Greenwood, 100 feet southeast of large dwelling, at northwest corner of highway bridge over Boxelder Creek; spike in root on north side of 18-inch pine tree	4,924.50
Greenwood, 1.1 miles northwest of, 30 feet west of road to Deadwood at point where timber road turns toward Nasby, across road from group of old log cabins, 250 feet northwest of highway bridge over Boxelder Creek, near two pine trees, one marked "U.S.G.S. B.M. W.T.," 15 inches in diameter southeast 18 feet, one 30 inches in diameter northeast 40 feet; iron post stamped "DW 5020"	5,021.213
Johnson ranch, 1.8 miles northeast of, 6 feet northwest of county road, 150 feet northeast of road crossing over Boxelder Creek; spike in root southwest side of 15-inch pine tree	5,101.17
Anderson ranch, 1,000 feet southeast of, 10 feet southwest of road; iron post stamped "DW 5204"	5,205.158
Nelson ranch, 2,000 feet southwest of, 60 feet southeast of road, 180 feet southwest of forks in road running south across Boxelder Creek; spike in north root of 24-inch pine	5,300.13

Slate Creek schoolhouse via Castle Creek and Cold Springs to Bulldog ranch.

Slate Creek schoolhouse, 1.5 miles northwest of, 25 feet northeast of intersection of Hill City and Lookout roads, center of east side and 1 foot below top of highest slate outcrop; copper bolt stamped "DW 6146"	6,147.358
Kinney ranch, 500 feet east of, 125 feet south of bridge over Castle Creek, on Hill City road, west side of road east of Castle Creek; iron post stamped "DW 5737"	5,738.497
Reynolds ranch, 1 mile south of, intersection of Rochford, Hill City, and Castle Creek roads; iron post stamped "DW 6029"	6,030.542
Shick ranch, 0.5 mile east of, 275 feet west of intersection of Rochford and Castle Creek roads, 50 feet north of road, 6 feet from highest point of outcrop, in slate ledge 12 feet higher than road; copper bolt stamped "DW 6007"	6,008.481

	Feet.
Johnson ranch, 700 feet northwest of, 2.5 feet north of section corner on township line, 250 feet north of Castle Creek road, 60 feet west of road to Smith ranch; iron post stamped "DW 6363"	6, 364. 598
Castle Creek, head of, in west side and 2 feet below top of limestone outcrop, 10 by 10 feet, 150 feet northeast of intersection of Castle Creek, Cold Springs, and Newcastle roads; copper bolt, stamped "DW 6536"	6, 537. 445
Thowell ranch, 0.5 mile west of, 25 feet southwest of fork of road to ranch; iron post stamped "DW 6769"	6, 770. 366
Cold Springs, 300 feet north of, 150 feet north of point where Cheyenne–Deadwood road crosses creek, 100 feet west of road, in limestone ledge, 15 feet higher than creek bed, which shows out of ground 10 feet in length and 2 feet high; copper bolt stamped "DW 6417"	6, 418. 399
Besant, 2.3 miles west of, north side of road near edge of small park; iron post stamped "DW 6547"	6, 548. 551
Besant, 0.2 mile southeast of, south side of road; iron post stamped "DW 6433"	6, 434. 586
Fish timber camp, 100 feet south of, 50 feet west of stable, south edge of road; iron post stamped "DW 6284"	6, 285. 521
Bulldog ranch, 75 feet east of track, 50 feet northwest from wagon road, 15 feet southwest of post, in mound of rock, marked "U. S. L. M. 73," in top of small flat rock; bronze tablet stamped "DW 5863"	5, 864. 398

Spearfish via Spearfish and Bear Gulch road to Powers sawmill site.

Spearfish, water table of Star & Bullock Building; bronze tablet stamped "DW 3647"	3, 648. 655
Brown ranch, 200 feet southwest of, south side of road; iron post stamped "DW 4224"	4, 225. 358
Brown ranch, 4.1 miles southwest of, 2.3 feet north of corner common to secs. 1, 6, 31, and 36, Tps. 5 and 6 N., Rs. 1 and 2 E.; iron post stamped "DW 5131"	5, 132. 324
Powers sawmill site, 400 feet north of, north side of road; iron post stamped "DW 5437"	5, 438. 252

Elmore via Cheyenne Crossing to Block ranch and return.

Elmore, west of section house; iron post stamped "DW 5218"	5, 219. 816
Cheyenne crossing, 20 feet northwest of, intersection of road to Elmore with old Deadwood-Cheyenne stage road; iron post stamped "DW 5308"	5, 309. 330
Block ranch, 75 feet northeast of, mouth of Deadhorse Canyon, west side of road; iron post stamped "DW 5610"	5, 611. 349
Block ranch, 1.8 miles northwest of, west side of town line, 1,000 feet south of corner common to secs. 24 and 25, R. 1 E., and secs. 19 and 30, R. 2 E.; iron post stamped "DW 6140"	6, 141. 356

EDGEMONT QUADRANGLE.

Ivanhoe via Minnekahta to Hot Springs.

Ivanhoe, 2,000 feet northeast of, 60 feet southeast of crossing of Pringle-Minnekahta road, 10 feet northeast of corner fence post; iron post stamped "DW 4443"	4, 444. 594

	Feet.
Minnekahta, in front of station; top of rail	4,162.8
Minnekahta, 800 feet northeast of station, 100 feet northeast of switch stand at east end of Y, 50 feet north of track, 5 feet southeast of corner fence post; iron post stamped "DW 4159"	4,160.563
Minnekahta, 3.5 miles east of, 850 feet east of road crossing, 40 feet north of track, 16 feet east of north-south wire fence; iron post stamped "DW 4061"	4,062.507
Erskine, road crossing at platform; top of rail	3,816.6
Erskine, 2,500 feet northeast of, 150 feet northwest of Minnekahta-Hot Springs road crossing, near bridge 5, 30 feet north of wagon road at nearest point, 2 feet south of rock mound, top of south corner of limestone ledge; copper bolt stamped "DW 3794"	3,795.585

Minnekahta along Chicago, Burlington & Quincy R. R. via Edgemont to S. & G. ranch.

Minnekahta, 800 feet northeast of station, 100 feet northeast of switch stand at east end of Y, 50 feet north of track, 5 feet southeast of fence corner post; iron post, stamped "4159 DW"	4,160.563
Arnold ranch, 300 feet northwest of, 50 feet west of railroad, east side of wagon road; iron post stamped "4058 DW"	4,059.334
Arnold ranch, 3 miles south of, 350 feet north and 300 feet east of railroad trestle 6, east bank of creek, 300 feet east of railroad; iron post stamped "3891 DW"	3,892.414
Chilson, 0.4 mile west of section house, 75 feet south of wagon-road crossing; iron post stamped "3795 DW"	3,796.516
Edgemont, 2.9 miles northeast of, 150 feet south of Red Canyon, 75 feet east of wagon road, 50 feet west of railroad; iron post stamped "3460 DW"	3,461.451
Edgemont, north end of Chicago, Burlington & Quincy R. R. Hotel park, 50 feet west of main track; iron post stamped "3449 DW"	3,450.584
Edgemont, 4 miles northwest of, 450 feet southeast of railway pile bridge 206, 100 feet southwest of railway track, northeast side of wagon road; iron post stamped "3463 DW"	3,464.527
Marietta, 80 feet southwest of, near track at section house, 25 feet northeast of wagon road; iron post stamped "3486 DW"	3,487.506
Marietta, 2.7 miles northwest of, 300 feet southeast of trestle 213, 100 feet southwest of railroad track, 200 feet north of wagon road; iron post stamped "3544 DW"	3,545.652
Argentine, 175 feet south of water tank, 100 feet southwest of main track, 40 feet northeast of wagon road; iron post stamped "3632 DW"	3,633.596
Moss Agate Creek, west bank, 1.8 miles southwest of junction with Cheyenne River, 100 feet west of steep bank, 70 feet above creek, and quarter of a mile west of it; iron post stamped "3612 DW"	3,613.554

Edgemont via Maitland post office and Cascade Springs to Hot Springs.

Edgemont, 2.1 miles southeast of, at top of bluff, 25 feet south of road; iron post stamped "3671 DW"	3,672.481
Edgemont, 5.8 miles southeast of, 75 feet southeast of intersection of Edgemont, Ardmore, and Maitland post-office roads; iron post stamped "3578 DW"	3,579.512
Edgemont, 8.6 miles southeast of, 25 feet north of road, top of ridge; iron post stamped "3575 DW"	3,576.382

	Feet.
Edgemont, 10.6 miles southeast of, 0.2 mile east of Plum Creek, 0.3 mile south of Cheyenne River, top of small ridge 25 feet south of road; iron post stamped "3350 DW"	3, 351. 475
Maitland post office (Brady ranch), 200 feet southwest of, quarter corner on south side of sec. 24, T. 9 S., R. 4 E.; iron post stamped "3327 DW"	3, 328. 069
Maitland post office, 2 miles northeast of, top of highest ridge on Maitland and Cascade wagon road, 25 feet north of road; iron post stamped "3521 DW"	3, 522. 481
T. 85, R. 4 E., southeast corner of, quarter of a mile northwest of Coffey Flat schoolhouse; iron post stamped "3261 DW"	3, 262. 415
Cascade Springs, 300 feet west of sanitarium, in sandstone rock 3 feet higher than creek, between wagon road and creek; bronze tablet stamped "3406 DW"	3, 407. 413
Cascade Springs, 3.4 miles northeast of, west side of canyon, 200 feet east of deserted house, 25 feet north of road; iron post stamped "3835 DW"	3, 836. 364
Cascade Springs, 5.9 miles northeast of, 3.6 miles southwest of Hot Springs, 25 feet west of road on ridge; iron post stamped "3826 DW"	3, 827. 323

Edgemont up Cottonwood Creek 6 miles, thence southeast to Provo, thence along Chicago, Burlington & Quincy R. R. to Ardmore.

Edgemont, 3 miles southwest of, 75 feet northwest of Cottonwood Creek, east side of railroad track; iron post stamped "3528 DW"	3, 529. 477
Edgemont, 6 miles southwest of, 800 feet southeast of Cottonwood Creek, about 800 feet north of draw running northwest and emptying into it, and about 900 feet north of two high buttes; iron post stamped "3634 DW"	3, 635. 318
Edgemont, 9.2 miles southwest of, junction of roads running south and southwest, at top of divide; iron post stamped "3839 DW"	3, 840. 390
Edgemont, 12 miles southwest of, 2.5 miles west of Provo, 10 feet north of abandoned wagon road to Provo, 1 mile south of sheep corral; iron post stamped "3710 DW"	3, 711. 422
Provo, 500 feet southeast of, 35 feet northeast of wagon road crossing; iron post stamped "3708 DW"	3, 709. 498
Provo, 3 miles east of, 50 feet north of Chicago, Burlington & Quincy R. R. track; iron post stamped "3632 DW"	3, 633. 359
Provo, 6 miles east of, 2 miles northwest of Rumford, 60 feet southwest of railway track; iron post stamped "3532 DW"	3, 533. 412
Rumford, 0.5 mile southeast of, 75 feet south of southeast end of siding, 65 feet southwest of main track, 300 feet east of wagon road; iron post stamped "3500 DW"	3, 501. 271
Rumford, 3 miles southeast of, 60 feet east of wagon road, 600 feet south of bridge over wagon road, 650 feet west of track; iron post stamped "3487 DW"	3, 488. 251
Rumford, 5.9 miles southeast of, 2 miles north of Ardmore, 25 feet east of wagon road, 500 feet west of railway track; iron post stamped "3527 DW"	3, 528. 177
Ardmore, 525 feet northwest of station, 80 feet north of road, 125 feet northwest of schoolhouse; iron post stamped "3553 DW"	3, 554. 213

Ardmore up Indian Creek to Cole ranch, thence north and east to Rumford.

	Feet.
Ardmore, 3.2 miles southwest of, 75 feet northwest of crossroads, 0.5 mile north of State line between South Dakota and Nebraska; iron post stamped "3666 DW"	3,667.239
T. 12 S., R. 3 E., quarter corner on west side of sec. 16, 2,100 feet north of State line; iron post stamped "3672 DW"	3,673.372
T. 12 S., R. 2 E., quarter corner on west side of sec. 13, 1,000 feet southwest of Simler's ranch; iron post stamped "3679 DW"	3,680.075
T. 12 S., R. 2 E., southeast corner of sec. 8, about 0.7 mile west of Cole ranch, northeast of bank of Alkali Creek; iron post stamped "3756 DW"	3,757.510
Cole ranch, about 4 miles northwest of, 200 feet east of east prong of Alkali Creek, at west end of low ridge; iron post stamped "3899 DW"	3,900.257
T. 11 S., R. 1 E., southwest corner of sec. 18, at top of divide between north and south forks of Camp Creek; iron post stamped "4138 DW"	4,139.361
T. 11 S., R. 2 E., near southwest corner of sec. 14, 10 feet north of road; iron post stamped "3909 DW"	3,910.203
T. 11 S., R. 3 E., southwest corner of sec. 16, top of low ridge; iron post stamped "3720 DW"	3,720.991
T. 11 S., R. 3 E., 1,000 feet north and 300 feet east of quarter corner on south side of sec. 14, top of low ridge; iron post stamped "3673 DW"	3,674.608

Rumford via Hat Creek to Maitland post office.

T. 10 S., R. 4 E., southwest corner of sec. 26, 1 mile southwest of Bar T ranch, 100 feet southeast of schoolhouse, 125 feet north of Hat Creek, in rock 8 by 12 inches and 6 inches above ground; aluminum tablet stamped "3443 DW"	3,444.041
T. 10 S., R. 4 E., near middle of sec. 10, 200 feet south of Pine Creek, 400 feet west of Hat Creek, 100 feet south of schoolhouse, 20 feet west of wagon road, in sandstone 15 by 10 inches, 7 inches above ground; aluminum tablet stamped "3383 DW"	3,384.433

HARNEY PEAK QUADRANGLE.

Redfern to Hill City.

Redfern, 2.6 miles southeast of, 75 feet east of crossing of Rochford and Hill City wagon road, 1,000 feet north of dwelling between bridges 61 and 62; spike in northeast side of pine tree	5,436.72
Hill City, 4.3 miles northwest of, 900 feet north of bridge 60, 3,000 feet east of county road crossing, 300 feet north of spring meadow, 400 feet west of house, 30 feet north of wagon road from Redfern to Hill City, in east side of rock outcrop, 10 feet above road, 3 feet north of small rock mound; copper bolt stamped "DW 5349"	5,350.506
Hill City, 120 feet south of station, in center of south end of lawn, 2 feet north of fence; iron post stamped "DW 4976"	4,977.714
Hill City, south end of town, 3,600 feet south of station, 75 feet east of track, 500 feet north of switch on branch line to Coats and Cowboy, 75 feet south of abandoned sawmill, in top of white quartz rock, 2 by 2 feet at surface; bronze tablet stamped "DW 5026"	5,027.604

Hill City to Custer.

	Feet.
Hill City, 4 miles south of, 1 mile southwest of switch at lumber spur, 470 feet northeast of crossing of Hill City-Custer wagon road, 235 feet southwest of southwest end of bridge 42, 100 feet north of limit post between railroad sections 10 and 9, about center of rock cut, 10 feet west of and 6 inches above track, top of rock projection from main wall of cut; copper bolt stamped "DW 5240"	5, 241. 537
Oreville, 25 feet northwest of track, 25 feet west of mail-bag catcher stand, 60 feet north of switch stand at north end of siding, on top of flat bowlder east of small rock mound; chisel mark	5, 338. 31
Oreville, 2,500 feet south of sawmill, 200 feet southeast of junction of Spring and Tenderfoot creeks, 250 feet south of crossing of Hill City-Custer wagon road, 100 feet west of bridge 37; copper nail in north side of pine tree, near ground	5, 366. 30
Custer, 6 miles northwest of, 1,000 feet north of tin mine, 500 feet northeast of Tenderfoot Springs, long rock cut in curve on east side of track, in white quartz rock, 2 by 2 foot face, on top of south end of cut; copper bolt stamped "DW 5696"	5, 697. 253
Custer, 3.5 miles northwest of, 250 feet north of crossing of Hill City-Custer wagon road, 50 feet east of road, in center of quartz outcrop, 1 foot south of loose rock mound, in top of 2 by 2 foot rock; bronze tablet stamped "DW 5749"	5, 750. 720
Custer, in front of ticket office, top of rail, main track	5, 304. 4
Custer, 950 feet southwest of station, 440 feet south of track, 500 feet east of axle grease factory, north side of group of rocks, 5 feet east of large blazed pine tree, 1 foot north of rock mound, in top of rock, 5 by 5 foot surface, 5 feet high on lower side; bronze tablet stamped "DW 5322"	5, 323. 665

Custer to Pringle.

Custer, 1.2 miles south of, 100 feet east of track on inside of curve, on opposite side of track from large jagged rock, at west end of rock ledge; copper nail in root on west side of pine tree	5, 374. 83
Custer, 1.8 miles south of, 900 feet south of log house, north of yellowish-brown house, 20 feet west of white reference post marked "P. S. 10°," north end of large rock in cut on west side of track; chisel mark	5, 426. 59
Custer, 2.7 miles south of, 0.5 mile south of top of divide, 85 feet northeast of Custer-Pringle road crossing over railroad, 800 feet north of log house, 25 feet east of wagon road, 2 feet southwest of rock mound, in rock 4 by 10 by 2 feet high; copper bolt stamped "DW 5469"	5, 470. 652
Mayo, 175 feet north of railroad section house, 75 feet northeast of road crossing, in rock 100 by 30 feet, 25 feet high, near southwest corner, 6 feet above ground; copper bolt stamped "DW 5190"	5, 191. 482
Pringle, 3,000 feet northeast of station, 300 feet south of Custer-Hot Springs road crossing over railroad, 250 feet north of whistling post marked "Pringle," 30 feet west of track, in south side of rock 100 by 30 feet, 20 feet high, 4 feet above ground; copper bolt stamped "DW 4879"	4, 880. 355
Pringle, in front of ticket office; top of rail, main track	4, 880. 4

Pringle to Ivanhoe.

	Feet.
Pringle, 1 mile southwest of, 40 feet south of road crossing near top of divide, 3 feet northeast of telegraph pole, point on southwest corner of limestone rock	4,951.89
Loring siding, 6,000 feet north of north switch stand, 180 feet west of crossing of Pringle-Minnekahta road, 280 feet northwest of bridge 11, in limestone rock 20 by 15 feet, 5 feet high, 15 feet northwest of pine tree, in top 3 feet from northwest corner; copper bolt stamped "DW 4697"	4,698.525
Argyle, in front of section house; top of rail	4,795.2
Argyle, 1,550 feet southwest of section house, 30 feet east of track, near north end of small cut, 2 inches above ground, in southeast end of sandstone rock 8 by 3 feet; copper bolt stamped "DW 4798"	4,799.660

Berne siding, 3.5 miles northwest of Custer, along public road to Bear Springs public road.

Pleasant View ranch, 0.5 mile southeast of, 0.5 mile northeast of Wright ranch, 800 feet south of small bridge on Custer-Deadwood road, 30 feet southeast of road from Wright ranch to Custer, 50 feet west of large pine tree blazed on west side, in large rock at north end of ledge 50 feet long, near center of top rock, about 15 feet above road; chisel mark	5,702.88
Wright ranch, 0.8 mile west of, 100 feet southeast of junction of two roads, 200 feet east of timber; spike in top of root on east side of detached 2-foot pine tree	5,767.37
Wright ranch, 1.5 miles west of, 1,300 feet east of small butte covered with white quartz rock, 3,000 feet east of fork in road, rocky ridge running across road northwest and southeast 30 feet south of county road, in large outcrop 30 by 30 feet 6 feet high, 7 feet west of northeast corner and 4 feet above ground, near three pine trees marked {U.S.G.S. B.M., W.T.}, one southeast 18 feet, one northeast 35 feet, and one northwest 35 feet; bronze tablet stamped "DW 5871"	5,872.599
Wright ranch, 2 miles west of, 45 feet west of fork in road, 1,700 feet west of small quartz-covered butte on north side of road; spike in root on north side of 2-foot pine tree	5,999.7
Wright ranch, 3 miles west of, 3,000 feet west of placer mine, 400 feet northwest of fork in road, 150 feet north of road to placer mine, 40 feet northeast of Custer-Bear Springs road; spike in root on north side of pine tree 18 inches in diameter	6,009.68
Henderson ranch, 2,000 feet east of, 75 feet northwest of fork in county roads, 30 feet north of Custer-Bear Springs road, near three pine trees marked "U.S.G.S. B.M. W.T.," one 15 inches in diameter southeast 133 feet, one 30 inches in diameter north 23 feet, one 24 inches in diameter northwest 49 feet; iron post stamped "DW 6060"	6,061.550
Peterson ranch, 1,400 feet northwest of, 50 feet west of right-angle bend in Custer-Bear Springs road; spike in root on northeast side of 2-foot pine tree	6,183.09
Peterson ranch, 1 mile west of, at foot of steep hill, 8 feet south of county road; spike in root on north side of 1-foot pine tree	6,282.80

	Feet.
Peterson ranch, 1.25 miles west of, in gap on top of divide between heads of French Creek and Hell Canyon, 10 feet north of Custer-Bear Springs wagon road, 5.25 feet northwest of southeast corner of sec. 33, T. 2 S., R. 3 E.; near two pine trees marked "U.S.G.S. B.M. W.T.," one 1 foot in diameter, west 11 feet; one 15 inches in diameter, east 30 feet; iron post stamped "DW 6443"	6, 444. 540
Bear Springs, 1.8 miles southeast of, 300 feet east of top of divide between Bear Springs and Bull Spring gulches, 5 feet north of Custer-Bear Springs road; spike in root on southeast side of 1-foot pine tree	6, 629. 95
Bear Springs, 1.25 miles southeast of, 30 feet northeast of Custer-Bear Springs road, 0.5 mile northwest of crossing over top of divide between Bear Springs and Bull Spring gulches, on east side of small park; copper nail in root on west side of 15-inch pine tree	6, 515. 44

Bear Springs to Buck Spring public road.

Alkali Spring, 1 mile northwest of, 520 feet northwest of fork of roads to Buck Spring and down west side of Hell Canyon, 65 feet northeast of Buck Spring road, near top of limestone rock 24 by 4 feet and 2½ feet high; location marked by two pine trees marked "U.S.G.S. B.M. W.T.," one 10 inches in diameter north 150 feet, one 18 inches in diameter southeast 180 feet; bronze tablet stamped "DW 6224"	6, 225. 638
Alkali Spring, 3.25 miles northwest of, 0.8 mile northwest of top of divide near southeast corner of park, 30 feet north of Custer-Buck Spring road; spike in root on northwest side of 30-inch pine tree	6, 231. 59
Alkali Spring, 2.5 miles northwest of, 4,000 feet east of road crossing over west fork of Hell Canyon, 25 feet south of Custer-Buck Spring road, in scattered timber on top of ridge, near three pine trees marked "U.S.G.S. B.M. W.T.," one 10 inches in diameter southeast 30 feet, one 10 inches in diameter west 65 feet, one 10 inches in diameter north 45 feet; iron post stamped "DW 6325"	6, 326. 910
West fork of Hell Canyon, 2,000 feet west of, 20 feet southwest of Custer-Buck Spring road; wire nail in root on north side of 15-inch tall dead pine tree	6, 252. 75
Buck Spring, 5.25 miles northeast of, 2.3 miles northeast of point where Custer-Buck Spring road descends into bottom of Gillette Canyon, 25 feet west of road, near two pine trees marked "U.S.G.S. B.M. W.T.," one northwest 40 feet, one southeast 75 feet; iron post stamped "DW 6193"	6, 194. 651
Buck Spring, 4.2 miles northeast of, 1.6 miles northeast of point where Custer-Buck Spring road enters Gillette Canyon, 8 feet southeast of road; spike in root on west side of 15-inch pine tree	6, 085. 92
Buck Spring, 4 miles northeast of, 30 feet north of Custer-Buck Spring road, on north side of clump of large trees 1.1 miles northeast of point where road enters bottom of Gillette Canyon; spike in root on south side of 18-inch pine tree	5, 982. 92
Gillette Canyon, top of slope, east side, 20 feet northwest of Custer-Buck Spring road at top of steep descent into bottom of canyon; spike in root in southeast side of 18-inch pine tree	5, 828. 94

	Feet.
Buck Spring, 3 miles east of, 30 feet southwest of and about 10 feet above Custer-Buck Spring road, 250 feet east of point where road crosses dry stream bed in Gillette Canyon after descending steep hill, in top of limestone outcrop 2 by 2 by 2 feet high; location mark by three pine trees marked "U.S.G.S. B.M. W.T.," one 15 inches in diameter east 250 feet, one 10 inches in diameter northwest 12 feet, one 12 inches in diameter south 45 feet; bronze tablet stamped "DW 5627"	5,628.738
Buck Spring, 2 miles east of, 30 feet north of Custer-Buck Spring road, 400 feet northwest of mouth of deep narrow gulch up which road runs, on bank 25 feet above road; spike in root on north side of 15-inch pine tree	5,699.13
Buck Spring, 1.8 miles east of, 6 feet northwest of Custer-Buck Spring road, 200 feet east of top of divide between Gillette and Buck Spring canyons; spike in root on southwest side of 18-inch pine tree	5,800.03
Buck Spring, 100 feet southeast of, 330 feet southwest of Kemp dwelling house, 45 feet west of road down Buck Spring Canyon, in top of north end of limestone rock, 4 by 6 feet, 18 inches above ground; location marked by two pine trees marked "U.S.G.S. B.M. W.T.," one 14 inches in diameter northwest 200 feet, one 15 inches in diameter southeast 20 feet; bronze tablet stamped "DW 5432"	5,433.697

Buck Spring to Hell Canyon and Pass Creek public road.

Buck Spring 0.7 mile south of, 45 feet northwest of road down canyon; spike in root on east side of 3-foot pine tree	5,340.66
Buck Spring, about 2 miles south of, 8 feet northwest of road down canyon, 6 feet southeast of dry rocky stream bed; spike in southeast side of 20-inch pine tree 6 inches above ground	5,175.06
Buck Spring, 3.2 miles south of, 150 feet east of dry stream bed in Buck Spring Canyon, 60 feet southeast of and about 10 feet above wagon road, near foot of a point topped with high vertical rock, where road again enters canyon after crossing ridge to northeast, in top of gray sandstone outcrop 3 feet wide and 2.5 feet high; location marked by three pine trees marked "U. S. G. S. B. M. W. T.," one 20 inches in diameter southeast 6 feet, one 5 inches in diameter southwest 50 feet, one 12 inches in diameter north 27 feet; bronze tablet stamped "DW 5050"	5,051.670
Buck Spring, 4.5 miles south of, 100 feet southeast of dry stream bed of Buck Spring Canyon, 500 feet south of old stone chimney near water hole 50 feet southeast of and 20 feet above road; spike in west side of 22-inch pine tree	4,897.04
3-C-S, or Campbell ranch, 700 feet southwest of, 80 feet east of fork in roads, 1,000 feet east of junction of Gillette and Buck Spring Canyons, on top of small rocky point; iron post stamped "DW 4727"	4,728.767
Babcock ranch, 0.8 mile northwest of, 1.2 miles southeast of Coe ranch, 30 feet south of Custer-Newcastle road, 200 feet east of junction of road from Babcock ranch, 400 feet east of timbered ravine down which Custer-Newcastle road runs; iron post stamped "DW 4950"	4,951.636
Barthold ranch, 0.25 mile east of, 500 feet northeast of Coon Creek, 60 feet north of intersection of two wagon roads; iron post stamped "DW 4670"	4,671.741

	Feet.
Drew ranch, 2,200 feet northwest of, 15 feet southwest of road from Barthold ranch, 35 feet southeast of northwest corner of sec. 2, T. 5 S., R. 1 E., on southeast bank of gulch; iron post stamped "DW 4373"	4,374.721
Drew ranch, 1.8 miles south of, 30 feet west of road to S & G. ranch, 800 feet southwest of two buttes capped with limestone bowlders, about 1 mile northeast of point where road crosses stream in Tepee Canyon, top of long hill; iron post stamped "DW 4422"	4,423.676
Drew ranch, 2.8 miles south of, 75 feet east of road to S. & G. ranch, 180 feet northwest of stream in Tepee Canyon, 300 feet northeast of remains of old log cabin, small outcrop of sandstone rock, 20 feet above bed of stream, on top of rock 1 by 1 foot in center of outcrop, 2 feet southeast of mound; chisel mark	4.201.77
Hell Canyon and Pass Creek, 3.2 miles north of junction of, 15 feet west of road from Drew ranch to S. & G. ranch, 1,100 feet south of junction with road down west side of Tepee Canyon, on top of ridge covered with scattered quartzite bowlders, 6 feet east of bowlder 12 by 8 by 5 feet, in top of rock 4 by 2 by 1 foot; bronze tablet stamped "DW 4294"	4,295.486
Hell Canyon and Pass Creek, 1.200 feet west of junction, 75 feet southwest of junction of road down Pass Creek with road from Drew ranch to S. & G. ranch, 24 feet southeast of road, 90 feet south of south bank of creek bed; iron post stamped "DW 3846"	3,847.834
Sullivan ranch, 1 mile east of, on south bank of Pass Creek, 250 feet east of mouth of small running stream, 40 feet southeast of road; spike in root on north side of 15-inch cottonwood tree	3,899.80
Sullivan ranch, 2.6 miles east of, 240 feet south of stream bed in Pass Creek Valley, 45 feet south of county road crossing over stream bed. 800 feet west of point where road runs up out of valley onto a flat prairie, on small point of land 10 feet above road; iron post stamped "DW 3988"	3,989.722
Sullivan ranch, 5.8 miles east of, 3,800 feet northeast of southwest corner of sec. 35, T. 5 S., R. 2 E., 25 feet north of county road from S. & G. ranch to Custer, 65 feet west of junction with dim road from northwest, about halfway up a long hill; iron post stamped "DW 4253"	4.254.797

Pass Creek to Loring siding public road.

Richardson ranch, 1.8 miles southwest of, 800 feet east of southeast fork of Pass Creek, 5 feet south of county road from S. & G. ranch to Custer; spike in root on northwest side of 2-foot pine tree	4,427.96
Richardson ranch, 1 mile southwest of, 15 feet northwest of road from S. & G. ranch to Pringle, at junction of road from southwest, in saddle on top of ridge; iron post stamped "DW 4594"	4,595.808
Richardson ranch, 500 feet southwest of dwelling, 65 feet southwest of county road; spike in root on north side of 20-inch pine tree	4,583.47
Richardson ranch, 2 miles east of, 20 feet east of road, 800 feet north of junction of roads, 900 feet south of junction with private road from Richardson ranch, on top of ridge about 1.25 miles west of Pleasant Valley; iron post stamped "DW 4796"	4,797.890

	Feet.
Eighteen Mile ranch, 0.8 mile west of, 1,200 feet north of Tutt ranch, 15 feet southwest of county road, 100 feet west of junction of road from Eighteen Mile ranch with road up Pleasant Valley, west side of Pleasant Valley, 3 feet northeast of wire fence; iron post stamped "DW 4649"	4,650.883
Eighteen Mile ranch, 1,800 feet northeast of, 180 feet southwest of fork in stream bed, 90 feet northwest of water hole, on northwest end of brown sandstone 5 by 3 feet and 1 foot high; circle and radial lines, chisel mark	4,692.37
Eighteen-Mile ranch, about 2 miles southeast of, 6 feet west of road from Eighteen-Mile ranch to Horgan ranch, 1,500 feet north of top of divide; spike in root on east side of 2½-foot pine tree	4,851.53
Horgan ranch, 2 miles northwest of, 15 feet west of road from Loring siding to Eighteen-Mile ranch, 350 feet south of top of divide over which road crosses; iron post stamped "DW 4916"	4,918.046
Horgan ranch, 0.8 mile southwest of, 27 feet southeast of road coming into ranch from southwest, 400 feet southwest of junction with road from Eighteen-Mile ranch, near north end of circular outcrop of flat rock, on top of southeast side of sandstone rock 5 by 3 by 1 foot; chisel mark	4,792.85

Point 2 miles east of Richardson's ranch southwest by McBeath ranch down East Fork of Hawkwright Creek, thence north to Pass Creek Valley.

McBeath ranch, 1.4 miles northeast of, 20 feet east of road to Custer, on south side of ridge of timber through which road passes, 6 feet east of dry sandy ravine; copper nail in root on northwest side of 15-inch pine tree	4,639.79
McBeath ranch, 1,600 feet northeast of, 35 feet southeast of road to Custer on southwest edge of timber, 300 feet southwest of point where road runs down dry rocky stream bed, near pine tree, marked "U.S.G.S. B.M. W. T.," east 30 feet; iron post stamped "DW 4512"	4,513.841
Cedar ranch, 1,300 feet northwest of, 370 feet south of gate in wire fence, 60 feet east of road; copper nail in root on west side of 15-inch dry pine stump 6 feet high	4,400.59
Cedar ranch, 500 feet west of, 140 feet west of gate in wire fence, 20 feet southwest of road; spike level with ground in root on northeast side of 12-inch pine tree	4,349.55
Cedar ranch, 2 miles south of, 20 feet west of road down Hawkwright Creek, 180 feet west of and about 30 feet above bed of east fork of creek, 600 feet north of point where road runs up out of valley and crosses ridge; near two pine trees marked "U.S.G.S. B.M. W.T.," one 5 inches in diameter south 70 feet, one 8 inches in diameter west 40 feet; iron post stamped "DW 4165"	4,166.790
Cedar ranch, 4 miles south of, 40 feet west of crossing of road over Hawkwright Creek, 500 feet south of spring; spike in root on south side of 15-inch cottonwood tree	4,035.11
Cedar ranch, 4.8 miles south of, 25 feet northeast of road down Hawkwright Creek, at junction with road from northwest, about 3,000 feet south of fork in creek, 0.5 mile west of creek; iron post stamped "DW 4021"	4,022.825

McBeath ranch, 2.5 miles west of, 70 feet northwest of road from McBeath and Cedar ranches to Pass Creek, at junction with road up ridge from the southwest, on top of watershed between Pass Creek and Hawkwright Creek, where road starts descent into Pass Creek basin; pine tree 15 inches diameter marked "U.S.G.S. B.M. W.T.," southeast 130 feet; iron post stamped "DW 4373"	Feet. 4, 374. 790

Pass Creek Valley north to Marsh ranch.

Roger's shack, 1.25 miles northeast of, 120 feet southeast of old S. & G.-Custer County road, 25 feet northeast of plank gate in wire fence on south side of Lindsay ranch pasture; spike in root on north side of 2-foot pine tree	4, 640. 83
Lindsay ranch, 0.8 mile east of, 18 feet southeast of old S. & G.-Custer County road, in small saddle on top of ridge, 40 feet northeast of crest, 600 feet south of fence on north side of pasture; near two pine trees marked "U.S.G.S. B.M. W.T.," one 5 inches in diameter northwest 60 feet, one 12 inches in diameter northeast 90 feet; iron post stamped "DW 4801"	4, 802. 541
Lindsay ranch pasture, 4,000 feet north of northeast corner, 40 feet west of old S. & G.-Custer County road, 450 feet north of junction with road from southwest, south side of belt of timber; wire spike in southeast side of 12-inch pine tree	4, 858. 61
Reynolds ranch, about 1 mile southwest of, 120 feet southeast of old S. & G.-Custer County road; wire spike in root on southeast side of 18-inch pine tree	5, 154. 61
Reynolds ranch, 0.5 mile southwest of, 30 feet east of old S. & G.-Custer County road, at junction of road from southeast, 0.25 mile south of point of fork of road to Reynolds ranch; iron post stamped "DW 5208"	5, 209. 692
Reynolds ranch, 1.2 miles north of, 35 feet southeast of old S. & G.-Custer County road, 165 feet northeast of cross roads in draw forming head of Pass Creek; copper nail in northwest side of 12-inch pine tree	5, 306. 46
Reynolds ranch, 2 miles north of, 150 feet southeast of road to Y 4 ranch, 0.5 mile southwest of timbered butte; copper nail in northwest side of 2-foot pine tree	5, 433. 91
Reynolds ranch, 2.8 miles north of, 20 feet east of road to Y 4 ranch, 0.5 mile northwest of timbered butte, near south end of strip of prairie; location marked by two pine trees marked "U.S.G.S. B.M. W.T.," one 6 inches in diameter south 180 feet, one 12 inches in diameter northeast 260 feet; iron post stamped "DW 5491"	5, 492. 664
Reynolds ranch, 3.8 miles north of, 50 feet east of road to Y 4 ranch, 160 feet southwest of gate in fence; wire spike in root on north side of 18-inch pine tree	5, 489. 57
Y 4 ranch, 0.5 mile southwest of, 30 feet north of road from Pass Creek, 25 feet east of ravine, 60 feet north of fence; wire spike in root on south side of 2-foot pine tree	5, 517. 36
Y 4 ranch, 0.5 mile northeast of, 20 feet southeast of road to Custer, in saddle on top of small ridge, near two pine trees marked "U.S. G.S. B.M. W.T.," one 5 inches in diameter west 145 feet, one 12 inches in diameter northeast 200 feet; iron post stamped "DW 5541"	5, 542. 589

	Feet.
Y 4 ranch, 2.5 miles northeast of, 10 feet southeast of road to Custer, 2,500 feet southwest of junction with old Custer-Newcastle stage road; wire spike in root on north side of 18-inch pine tree	5,673.05

Carr ranch along Custer-Newcastle public road via Fourmile, Marsh ranch, and Ward ranch, across Hell Canyon to point about 0.8 mile north of Babcock ranch.

Carr ranch, 300 feet northeast of, 3 miles southwest of Custer, in spherical rock outcrop 100 feet southeast of road; witness trees, one 45 feet east, 30-inch pine, one 30 feet south, 15-inch pine; bronze tablet stamped "DW 5475"	5,476.689
Fourmile, Hendricks ranch, 500 feet east of, 3 feet west of mile board at the intersection of the Dudley road with Custer-Newcastle road, 4.5 miles southwest of Custer; iron post stamped "DW 5336"	5,337.561
Fourmile, 2 miles west of, 0.5 mile east of Marsh ranch; nail in root of 18-inch pine 40 feet south of road	5,475.17
Marsh ranch, 800 feet west of, top of large flat rock on east edge of road, level with road, in west bank of dry creek channel, 125 feet north of crossing; pine witness tree, 30 inches in diameter, 70 feet east of south; pine witness tree, 30 inches in diameter, 50 feet east of south; bronze table stamped "DW 5453"	5,454.668
Ward ranch, 300 feet south of, 50 feet north of road; 18-inch pine witness tree 30 feet east; bronze tablet set in rock stamped "DW 5614"	5,615.495
Ward ranch, 1 mile west of, on south edge of road; nail in root of 15-inch pine tree	5,597.88
Ward ranch, 2 miles west of, 1 mile north of Smith ranch, at junction of ravine with Hell Canyon on south edge of road, 75 feet east of road down Hell Canyon; 10-inch pine witness tree 50 feet southeast, 20-inch pine witness tree 165 feet northeast; bronze tablet stamped "DW 5090"	5,091.596
Smith ranch, 3 miles west of, 800 feet west of intersection of middle and south roads over Hell Canyon, on top of divide between west Hell Canyon and east prong of Tepee Canyon, in limestone 3 by 2 by 1½ feet high, 100 feet northwest of road; 15-inch pine witness tree 200 feet north, 12-inch pine witness tree 65 feet southwest; bronze tablet stamped "DW 5358"	5,359.529
Smith ranch, 5 miles west of, 25 feet north of road, 100 feet west of middle prong of Tepee Canyon; nail in root of 12-inch pine	5,100.04
Smith ranch, 6 miles west of, 25 feet south of road, 900 feet east of section corner, on line between ranges 1 and 2, near foot of ridge; 20-inch pine witness tree 285 feet east, 24-inch pine witness tree 250 feet northeast; iron post stamped "DW 5094"	5,095.542
Smith ranch, 8 miles west of, on north edge of road, 300 feet west of top of ridge, 0.25 mile west of road running to Babcock ranch; point on large flat rock	5,044.72

Point on Custer-Deadwood public road 0.5 mile southeast of Pleasant View ranch, half mile northeast of Wright ranch, and 30 feet southeast of road from Wright ranch to Custer northwest to James Dwyer's ranch.

Mahnke ranch, 0.5 mile south of, 35 feet west of intersection of old stage road from Custer to Deadwood and road running to Hill City via Tenderfoot, 0.5 mile southeast of Junction schoolhouse; 15-inch pine witness tree 120 feet northeast, 18-inch pine witness tree 120 feet northeast; iron post stamped "DW 6106"	6,107.490

	Feet.
Mahnke ranch, 1.5 miles north of, 10 feet east of road; nail in root of 12-inch pine tree	6,032.11
Vonderlehr ranch, 275 feet north of, east side of road where it turns northwest on north side of valley; 24-inch pine witness tree 120 feet northwest, 24-inch pine witness tree 300 feet northeast; iron post stamped "DW 5818"	5,819.481
Vonderlehr ranch, 2 miles north of, 20 feet east of road, 300 feet north of top of ridge at Spring Creek; nail in root of 24-inch pine tree	5,943.55
Jackson ranch, 800 feet west of, at west edge of road, 100 feet west of small creek; 30-inch pine witness tree 170 feet northeast, 36-inch pine witness tree 265 feet northwest; iron post stamped "DW 5833"	5,834.468
Jackson ranch, 1.25 miles north of, 50 feet west of road; nail in root of 10-inch pine tree	5,949.55
Simpson ranch, 400 feet northeast of, in rock outcrop on point of ridge on east side of road; 18-inch pine witness tree 85 feet west; 15-inch pine witness tree 35 feet north; bronze tablet stamped "DW 6123"	6,124.371
Gillette ranch, 350 feet east of, in rock outcrop 20 feet long and 4 feet high, 15 feet above and 25 feet northeast of road at angle of road, 175 feet northwest of bridge over Slate Creek; 24-inch pine witness tree 370 feet south; bronze tablet stamped "DW 6243"	6,244.553
Gillette ranch, 1.1 miles north of, triangular stone 18 inches high with 2 feet base, 40 feet west of road, 75 feet east of Slate Creek; top surface	6,106.99
Cramer ranch, 0.4 mile north of, 20 feet south of road forks; 36-inch pine witness tree 325 feet northeast; 30-inch pine witness tree 425 feet southwest; iron post stamped "DW 5901"	5,902.373

Dwyer ranch east to Tigerville, on Chicago, Burlington & Quincy R. R.

Jim Dwyer ranch, 800 feet northwest of, 275 feet north of road; iron post set for township corner on base line, marked "Sec. 1 N., R. 3 E.," on northwest side and "R. 4 E." on northeast side, stamped "DW 5837"	5,838.898
Jim Dwyer ranch, 1 mile east of, south of road; nail in root of 10-inch pine tree	5,863.35
Mrs. Dwyer ranch (Tigerville), 100 feet east of road intersection; nail in root of 24-inch pine tree	5,486.52

Point 1.25 miles southeast of Bear Springs on Custer road to Bear Springs, Preacher Spring, and head of Castle Creek, thence north to Deadwood-Newcastle road, thence east to Bulldog ranch on Chicago, Burlington & Quincy R. R.

Bear Springs, in flat limestone outcrop 12 by 15 feet, 130 feet east of creek, 500 feet southeast of cabin, 50 feet below timber line, 350 feet southeast of road, 600 feet northeast of road; 18-inch pine witness tree 400 feet northwest; 40-inch pine witness tree 250 feet northeast; copper bolt stamped "DW 6490"	6,491.644
Bear Springs, 2.25 miles north of, in center and upper side of flat limestone outcrop, 135 feet northeast of road, on top of divide between head of Gillette Canyon and Hell Canyon, outcrop 60 feet by 30 feet; 15-inch pine witness tree 175 feet south; 12-inch pine witness tree 310 feet northwest; copper bolt stamped "DW 6912"	6,913.7
Bear Springs, 3.8 miles northwest of, 75 feet north of road; nail in root of 15-inch pine tree	6,666.08

	Feet.
Bear Springs, 4 miles northwest of, 25 feet east of road from Gillette Canyon to Bear Springs, on southeast side of Gillette Park at foot of ridge dividing branch of Gillette Canyon toward Bear Springs from branch to head of Spring Creek, 800 feet south of the intersection of the two branches of Gillette Canyon, near the intersection of the roads running to Bear Springs, Spring Creek, down Gillette Canyon, and north through Gillette Park; witness tree 190 feet northeast of 20-inch pine tree; witness tree 400 feet southeast of 30-inch pine tree; iron post stamped "DW 6611"	6, 612. 630
Preacher Spring main road and Gillette Canyon road, 5.1 miles east of intersection on Preacher Spring road; highest point of rock 12 by 12 inches 30 feet south of road	6, 561. 96
Preacher Spring main road and Gillette Canyon road, 3 miles east of intersection, 150 feet north of road; nail in root of 24-inch pine tree	6, 463. 42
Preacher Springs main road and Gillette Canyon road, 3 miles east of intersection, at intersection with a ravine from the south with Gillette Canyon, in second limestone outcrop from the north, at foot of cliff and 40 feet south of northwest point of cliff, 5 feet above level of surface in outcrop 10 feet high; 30-inch pine witness tree 280 feet north; 24-inch pine witness tree 300 feet southwest; copper bolt stamped "DW 6374"	6, 375. 451
Preacher Spring main road and Gillette Canyon road, 1 mile east of intersection; nail in root of 18-inch pine tree 50 feet east of road	6, 209. 26
Preacher Spring main road and Gillette Canyon road, 0.3 mile west of intersection, in east end and 8 inches below top of limestone outcrop 5 feet long and 2 feet high, 75 feet north of road and 6 feet higher than road; 18-inch pine witness tree 25 feet north; 24-inch pine witness tree 125 feet northeast; copper bolt stamped "DW 6129"	6, 130. 641
Graham ranch road, 1 mile northeast of intersection with, 20 feet east of road; nail in root of 24-inch dead pine tree	5, 965. 19
Graham ranch road, 25 feet west of intersection of, 4 miles east of Graham ranch; 30-inch pine witness tree 45 feet north; 30-inch pine witness tree 125 feet northeast; iron post stamped "DW 6167"	6, 168. 623
Graham ranch, 3 miles east of, 20 feet west of road; nail in root of 18-inch pine tree	6, 222. 60
Graham ranch, 1 mile east of, on south side of road; nail in root of 15-inch pine tree	6, 093. 09
Graham ranch, 1,000 feet south of, in blue limestone outcrop 12 by 12 inches, 15 feet east of road on east side of Hay Canyon, 20 feet east of foot of hill; 24-inch pine witness tree 135 feet north, 30-inch pine witness tree 280 feet southeast; copper bolt stamped "DW 5752"	5, 753. 694
Moon ranch, 1.25 miles south of, 45 feet east of road; nail in root of 18-inch dead pine tree	6, 147. 07
Moon ranch, 65 feet south of cabin, in limestone outcrop 18 by 24 inches; 10-inch pine witness tree 170 feet north, 24-inch pine witness tree 85 feet west; copper bolt stamped "DW 6273"	6, 274. 932
D. W. Thompson ranch, 2.5 miles south of, 75 feet east of road; nail in root of 40-inch pine tree	6, 404. 77
D. W. Thompson ranch, 1.25 miles south of, 50 feet west of road; nail in root of 30-inch pine tree	6, 387. 49

	Feet.
D. W. Thompson ranch, 0.7 mile south of, 25 feet east of intersection of Newcastle road with road south; 12-inch pine witness tree 50 feet east, 18-inch pine witness tree 265 feet southwest; iron post stamped "DW 6480"	6,481.610
D. W. Thompson ranch, 0.25 mile south of, 90 feet east of road; nail in root of 15-inch pine tree	6,512.67
D. W. Thompson ranch, 1.25 miles east of, in limestone outcrop 24 by 18 feet, 6 feet higher than road, 40 feet southeast of intersection of Preacher Spring road with Newcastle road; 36-inch pine witness tree 250 feet west, 18-inch pine witness tree 185 feet southeast; copper bolt stamped "DW 6588"	6,589.585
Woodward ranch, 2.25 miles south of, stone 2 feet by 1 foot, 40 feet east of road, beside stake; highest point of stone	6,570.13

Intersection of Preacher Spring, Ditch Creek, Spring Creek, and Bear Springs roads north to head of Ditch Creek.

Bear Springs, 5 miles northwest of, 2.8 miles southeast of head of water in Ditch Creek, 12 feet east of road, 100 feet southeast of limestone outcrop, 300 feet north of top of ridge; highest point of 18-inch black bowlder with broken corner	6,599.46
Bear Springs, 5.5 miles northwest of, 2.25 miles southeast of head of water in Ditch Creek, 2 feet northeast of corner of SE. ¼ and SW. ¼ sec. 36, T. 1 S., R. 2 E., and NE. ¼ and NW. ¼ of sec. 1, T. 2 S., R. 2 E., 100 feet west of road, 25 feet east of dry creek; 24-inch pine witness tree 425 feet southwest; iron post stamped "DW 6571"	6,572.657
Ditch Creek, head of, in limestone outcrop 10 by 10 feet and 2 feet high, 85 feet east of road and 15 feet higher than road, 400 feet south of spring at head of Ditch Creek; 24-inch pine witness tree 180 feet northeast, 15-inch pine witness tree 280 feet west; bronze tablet stamped "DW 6410"	6,411.606

Sheridan via Hill City to McAdam ranch.

Sheridan, 3.2 miles southwest of, 100 feet south of J. R. stamp mill, 75 feet northwest of Lambert house, 60 feet west of intersection of road; iron post stamped "DW 4736"	4,737.463
Hill City, 120 feet south of railroad station, in center of south end of lawn, 2 feet north of fence; iron post stamped "DW 4976"	4,977.714
McAdam ranch, 100 feet northwest of, south edge of road; iron post stamped "DW 4947"	4,948.359

Richardson ranch via Lame Johnny Creek to Tinsley ranch.

Richardson ranch, 600 feet northeast of, 3.5 miles from Custer; iron post stamped "DW 5187"	5,188.514
Wood ranch, 0.8 mile southeast of, 400 feet south of abandoned sawmill, 100 feet west of road, 25 feet south of rock ledge 5 by 15 feet, 2 feet high, in solid rock; bronze tablet stamped "DW 5027"	5,028.591
Tinsley ranch, 800 feet east of, in granite rock, 10 feet diameter, 4 feet high, on south side of road, 300 feet west of top of divide; bronze tablet stamped "DW 5109"	5,110.536

Clinkenbeard ranch to Pringle.

Clinkenbeard ranch, 300 feet southwest of, at intersection of Pringle, Hot Springs, and Buffalo Gap roads; iron post stamped "DW 4532"	4,533.509

	Feet.
Bowman ranch, fork of road to, north side of road; iron post stamped "DW 4716"	4,717.583
Pringle, 0.4 mile north of; copper bolt stamped "DW 4879"	4,880.355

Point near Dwyer ranch.

Jim Dwyer ranch, 800 feet northwest of, 275 feet north of road; iron post set in township corner on base line, marked "sec. 5, T. 1 N., R. 3 E.," on northwest and "R. 4 E." on northeast, stamped "DW 5837"	5,838.898

HERMOSA QUADRANGLE.

Bench mark near Sheridan.

Sheridan, 0.2 miles south of, 200 feet northwest of Barthold ranch, west of intersection of Sheridan, Hill City, and Keystone roads; iron post stamped "DW 4601"	4,602.471

Beardsley ranch via Keystone and Glendale to Hayward.

Beardsley ranch, 0.5 mile northeast of, 25 feet north of bridge over Battle Creek, in granite rock east side of road; bronze tablet stamped "DW 4734"	4,735.348
Keystone, 225 feet west of south end of business street, 150 feet southwest of Nick Shoemaker house, north side of road, bench of rock 2 by 5 feet, 3 feet higher than road; aluminum tablet stamped "DW 4340"	4,341.224
Harney schoolhouse, 300 feet east of, in large rock 50 feet southeast of intersection of Keystone, Rockerville, and Glendale roads; bronze tablet stamped "DW 4198"	4,199.356
Glendale, 0.4 mile south of, 100 feet east of intersection of Glendale, Spokane, and Hayward roads, in rock 8 by 10 feet and 3 feet high; bronze tablet stamped "DW 4244"	4,245.339
Hayward, west side of town, 175 feet east of Battle Creek, 50 feet south of intersection of Glendale, Rockerville, and Hermosa roads, in rock 15 by 8 feet, 3 feet high; bronze tablet stamped "DW 3812"	3,813.417

Hayward north to Rockerville.

Hayward, 3.5 miles north of, on ridge west of road; iron post stamped "DW 4507"	4,508.258
Rockerville, west end of town, southeast side of intersection of Hill City, Keystone, and Rockerville roads; iron post stamped "DW 4369"	4,370.215

Bench marks near Baker ranch.

Sheridan, 2 miles northeast of, 50 feet northeast of intersection of Sheridan, Pactola, and Rapid roads, in stone 3 by 3 feet projecting 18 inches above ground; bronze tablet stamped "DW 4553"	4,554.481
Baker ranch, 800 feet southeast of, north side of road; iron post stamped "DW 4495"	4,496.163

Chicago & Northwestern Ry. bridge over Spring Creek to Rockerville.

Spring Creek, 0.5 mile north of, 90 feet southwest of crossing of county road and railroad; iron post stamped "DW 3326"	3,327.584

	Feet.
McMinn ranch, 350 feet northeast of, northeast side of intersection of road down Spring Creek with Rapid-Hermosa road; iron post stamped "DW 3350"	3,351.323
McMinn ranch, 1 mile west of, 25 feet north of road; copper nail in root of 18-inch elm tree	3,382.34
McMinn ranch, 2 miles west of, northeast corner of bridge over Spring Creek; copper nail in root of 15-inch cottonwood tree	3,420.60
McMinn ranch, 2.8 miles west of, 675 feet north of Erb ranch, 40 feet north of road, in sandstone 5 by 15 feet and 2 feet high; bronze tablet stamped "DW 3457"	3,458.387
Blair ranch, 400 feet northwest of, 45 feet northeast of intersection of Spring Creek, Rapid, and Rockerville roads; iron post stamped "DW 3511"	3,512.426
Blair ranch, 0.9 mile west of, north side of road; copper nail in root of 15-inch pine	3,704.93
Wright ranch, 1 mile east of, top of divide between Spring Creek and Rockerville Gulch, north side of road; iron post stamped "DW 4329"	4,330.311
Wright ranch, 800 feet west of, north side of road; copper nail in root of 12-inch pine	4,341.31

Rockerville via McNown, Murphy, and Peterson ranches to Hermosa.

McNown ranch, 0.5 mile northwest of, 100 feet north of road, in limestone rock 6 by 2 feet outcropping in side of rocky hill, 20 feet higher than road; bronze tablet stamped "DW 4324"	4,325.700
McNown ranch, 0.9 mile southeast of, 25 feet west of road; copper nail in root of 6-inch pine	4,249.81
McNown ranch, 2.9 miles southeast of, 1.7 miles northwest of Murphy (Red Earth) ranch, 20 feet north of road on top of divide, in sandstone 4 by 2 feet, 15 inches high; bronze tablet stamped "DW 4063"	4,064.405
Murphy ranch, 1 mile southwest of, 1.4 miles northwest of Peterson ranch; 300 feet northwest of junction of roads, on bank of channel in gulch; copper nail in root of 8-inch pine tree	3,600.19
Peterson ranch, 0.2 mile northwest of, northeast side of junction of Rockerville road with Hayward-Hermosa road; iron post stamped "DW 3525"	3,526.381
Peterson ranch, 0.8 mile south of, 100 feet northwest of Hayward-Hermosa road ford of Battle Creek, north bank of Battle Creek; copper nail in root of 20-inch oak tree	3,456.87
Beatty ranch, 0.6 mile east of, 450 feet southwest of intersection of the Squaw Creek and Battle Creek roads; iron post stamped "DW 3349"	3,350.261
Hermosa, 150 feet southwest of station, 60 west of track, in southwest corner of station agent's private yard; iron post stamped "DW 3300"	3,301.683

Glendale via Spokane and Farmer, Ray, and Clark ranches to Fairburn.

Spokane, 500 feet northwest of post office, 300 feet north of schoolhouse, in granite rock 8 by 10 feet and 18 inches high, on west side of road; bronze tablet stamped "DW 4521"	4,522.319
Farmer ranch, 1.6 miles southeast of, on north bank of ravine 60 feet east of road, in rock 3 feet high; bronze tablet stamped "DW 4086"	4,087.33?

Feet.

Ray ranch, southwest side of, intersection of Spokane, Hermosa, and Custer roads; iron post stamped "DW 3650" 3,651.371

Clark ranch, 0.3 mile east of, 350 feet north of Dry Creek, 50 feet south of cut-off road to Fairburn; iron post stamped "DW 3780" 3,781.914

Clark ranch, 0.7 mile southeast of, south side of road; copper nail in root of 12-inch elm tree 3,696.64

Laning ranch, 2.8 miles southeast of, top of ridge 1,000 feet east of gulch running into French Creek, north side of road, 375 feet southeast of quarter-section corner; iron post stamped "DW 3700" 3,701.225

Smith ranch, 0.5 mile north of, southwest side of road crossing, 2.5 miles west of Fairburn; iron post stamped "DW 3430" 3,431.212

Fairburn, 200 feet northeast of station, 40 feet northeast of county-road crossing; iron post stamped "DW 3310" 3,311.660

Clark ranch to Richardson ranch via Hare and McClelland ranches.

Fay ranch, 2.5 miles northwest of, 500 feet southeast of top of ridge, in white limestone, 2 by 4 feet and 1 foot high, on west side of road; bronze tablet stamped "DW 4223" 4,224.520

Hare ranch, 2.1 miles west of, 1 mile southwest of divide, between French Creek ravine and Squaw Creek, in granite ledge 3 feet higher than road on west side of road, on south bank of channel in ravine; bronze tablet stamped "DW 4664" 4,665.528

McClelland ranch, 0.1 mile west of, granite ledge north of and 4 feet higher than road; bronze tablet stamped "DW 5010" 5,011.555

Combe ranch to Gould ranch.

Combe ranch, 0.3 mile south of, on west side of road; iron post stamped "DW 4696" 4,697.681

Kenoyer ranch, 0.6 mile east of, on north side of road in rock 24 inches high, at point of rock outcrop 10 feet high; bronze tablet stamped "DW 4244" 4,245.487

McVey ranch, 1.7 miles east of, 300 feet north of intersection of Fairburn, Buffalo Gap, and Custer roads; iron post stamped "DW 3862" 3,863.520

Dowe ranch, 1.3 miles southeast of, 150 feet north of road down west branch of Lame Johnny Creek, 200 feet southwest of road from Fairburn, 600 feet west of intersection of roads, 1 mile southeast of Lame Johnny Creek, in sandstone outcrop 60 feet long; bronze tablet stamped "DW 3745" 3,746.222

Gould ranch, 0.4 mile northwest of, 2 feet northwest of northwest corner of sec. 21, T. 5 S., R. 7 E., on Buffalo Gap-Rapid road, 250 feet southwest of junction with road up Lame Johnny Creek; iron post stamped "DW 3482" 3,483.372

Parker ranch via Highland ranch to Otey ranch.

Parker ranch, 1.8 miles west of, at intersection of Custer, Buffalo Gap, and Lame Johnny Creek roads; iron post stamped "DW 4312" 4,313.460

Highland ranch, 0.4 mile northwest of, 75 feet east of intersection of Custer, Buffalo Gap, and Pringle roads, in rock outcrop 4 feet wide and 2 feet high; bronze tablet stamped "DW 4373" 4,374.607

Otey ranch, 0.4 mile north of, on south side of road at intersection of road to Reeve ranch; iron post stamped "DW 4617" 4,618.514

Fairburn via Richardson and Grimley ranches to Nelson ranch.

	Feet.
Fairburn, 3 miles east of, 50 feet southeast of southeast corner of sec. 28, T. 4 S., R. 8 E., 50 feet southeast of intersection of roads, 250 feet north of bridge over French Creek; iron post stamped "DW 3184"	3, 185. 307
Richardson ranch, 750 feet east of, 500 feet south of north quarter section corner of sec. 14, T. 5 S., R. 8 E., on west side of road; iron post stamped "DW 3298"	3, 299. 341
Richardson ranch, 3.1 miles south of, 1.4 miles south of French Creek divide, top of ridge, 20 feet west of road; iron post stamped "DW 3179"	3, 180. 133
Grimley ranch, 0.5 mile south and 0.5 mile east of, north side of road on top of ridge; iron post stamped "DW 3021"	3, 022. 249
Nelson ranch, 2.3 miles southwest of, southeast corner of sec. 21, T. 6 S., R. 8 E., 450 feet northwest of road; iron post stamped "DW 3183"	3, 184. 180

Wood ranch to Wind Cave ranch.

Wood ranch, 600 feet southwest of, 500 feet east of bridge over Beaver Creek, 5 feet south of south fence, on large outcrop of rock, 1 foot above ground; bronze tablet stamped "DW 3365"	3, 366. 436
Johnson ranch, 1.7 miles west of, on south side of road at junction of cut-off from Buffalo Gap-Custer road, foot of round hill with limestone ledge at top; iron post stamped "DW 3502"	3, 503. 446
Martin Valley ranch, 2.2 miles west of, south side of road, in ledge of limestone 20 by 30 feet; bronze tablet stamped "DW 3810"	3, 811. 608
Wind Cave ranch, 0.5 mile southeast of, 250 feet west of intersection of Buffalo Gap road with Wind Cave-Hot Springs road; iron post stamped "DW 4158"	4, 159. 580
Wind Cave ranch, 3.3 miles southeast of, west side of high ridge, in limestone rock on south side of road; bronze tablet stamped "DW 4233"	4, 234. 706

Grimley ranch via Cheyenne River and Morris, Smith, Stinger, Gramberg, and Bennett ranches to point 2 miles south of Brennan.

Harrison Flat schoolhouse, 1 mile north and 1 mile east of, southeast corner of SW. ¼ sec. 8, T. 6 S., R. 9 E.; iron post stamped "DW 2964"	2, 965. 193
Harrison Flat schoolhouse, 3.2 miles northeast of, 1.7 miles south of mouth of Cottonwood Creek, west side of Cheyenne River bottom where road comes down bluff; nail in 10-inch cottonwood tree	2, 792. 21
Cottonwood Creek, 500 feet southwest of mouth of, west side of Cheyenne River bottom, south side of Cottonwood Creek bottom, 50 feet southwest of junction of trails running down Cottonwood Creek; iron post stamped "DW 2775"	2, 776. 102
Ayres ranch, 0.2 mile southwest of, on west line of Pine Ridge Indian Reservation, 700 feet south of Cheyenne River, quarter mile east of west corner of secs. 13 and 24, T. 5 S., R. 9 E., 150 feet north of road in side of Indian monument; iron post stamped "DW 2738"	2, 739. 355
Cheyenne River, bed of, at northwest corner of Pine Ridge Indian Reservation	2, 729. 40

	Feet.
Ayres ranch, 3 miles northwest of, top of divide between French Creek and Cheyenne River, 25 feet north of road; iron post stamped "DW 3270"	3, 270. 181
Morris ranch, 75 feet southwest of, 9 miles east of Fairburn on north side of road, north side of French Creek; iron post stamped "DW 3008"	3, 009. 210
Morris ranch, 3.3 miles northwest of, about 0.5 mile northeast of junction of Alkali and Dry creeks, 500 feet south of junction of road to Battle Creek with Dry Creek-Hermosa road; iron post stamped "DW 3076"	3, 077. 066
Smith ranch, 0.5 mile north of, southeast corner of sec. 32, T. 3 S., R. 9 E., 0.25 mile west of road from French Creek to Hermosa; iron post stamped "DW 3162"	3, 163. 078
Stinger ranch, 1 mile southwest of, 75 feet southeast of intersection of roads to Hermosa, Battle Creek, and Cheyenne River; iron post stamped "DW 3212"	3, 213. 032
Stinger ranch, 0.6 mile east of, southeast corner of NE. ¼ sec. 7, T. 3 S., R. 9 E.; iron post stamped "DW 3137"	3, 138. 199
Stinger ranch, 1 mile east and 2.7 miles north of, 0.3 mile south of southeast corner of sec. 30, T. 2 S., R. 9 E., 30 feet southwest of road crossing; iron post stamped "DW 3278"	3, 279. 075
Vohmer ranch, 250 feet east of, on west side of road, 725 feet south of northeast corner of sec. 7, T. 2 S., R. 9 E., 450 feet south of Spring Creek; iron post stamped "DW 3133"	3, 134. 095
Gramberg ranch, 1 mile northwest of, at southwest corner of NW. ¼ sec. 31, T. 1 S., R. 9 E., 100 feet north of crossroads; iron post stamped "DW 3216"	3, 217. 075
Bennett ranch, 0.7 mile northeast of, at southeast corner of SW. ¼ sec. 17, T. 1 S., R. 8 E., 100 feet south of road; iron post stamped "DW 3155"	3, 156. 074
Brennan, 2 miles south of, 250 feet southeast of county road crossing, 20 feet southwest of county road, southwest corner of Getchell ranch, 1 foot south of north quarter corner of sec. 14, T. 1 S., R. 8 E.; iron post stamped "DW 3160"	3, 161. 695

Buffalo Gap to Brennan.

Beaver Creek, on bridge, 15 feet above stream; top of rail	3, 260. 1
Buffalo Gap, 4.2 miles northeast of, 350 feet northeast of bridge H 112, 200 feet southeast of track, 100 feet southeast of wagon road, 2.5 feet east of fence corner post; iron post stamped "DW 3265"	3, 266. 605
Melvin siding, 180 feet south of, north switch stand, west end of masonry culvert H 121, in top of southwest corner of coping stone; bronze tablet stamped "DW 3396"	3, 397. 735
T. 5 S., R. 7 E., 675 feet east and 30 feet north of south quarter corner of sec. 4, 700 feet north of section house 10, 60 feet west of track, 40 feet east of county road; iron post stamped "DW 3604"	3, 605. 576
Fairburn, 2.5 miles southwest of, 1,190 feet south of east quarter corner of sec. 27, T. 4 S., R. 7 E., 3 feet northwest of railroad fence, 60 feet southeast of angle in county road; iron post stamped "DW 3420"	3, 421. 612
Fairburn, 200 feet northeast of station, 40 feet northeast of county road crossing; iron post stamped "DW 3310"	3. 311. 660

	Feet.
Hermosa, 5.8 miles south of, 270 feet north of section house 12, 60 feet southeast of county road crossing 6 feet northwest of fence corner post; iron post stamped "DW 3430"	3,431.818
Hermosa, about 3 miles southwest of, 880 feet north of southeast corner of sec. 12, T. 3 S., R. 7 E., 180 feet north of bridge H 159, in center of county road lane at bend in road; iron post stamped "DW 3458"	3,459.655
Hermosa, 150 feet southwest of station, 60 feet west of track, in southwest corner of station agent's private yard; iron post stamped "DW 3300"	3,301.683
Hermosa, 4.3 miles north of, 740 feet west of east side and 35 feet south of north side of sec. 8, T. 2 S., R. 8 E., 115 feet southwest of county road crossing, 400 feet southeast of dwelling house, 50 feet northwest of track, 4 feet north of fence corner post; iron post stamped "DW 3503"	3,504.642
Spring Creek, 200 feet south of, 200 feet south of section house 14, east end of stone culvert H 185½, on projection on top of south end of coping stone; chisel mark	3,294.39
Spring Creek, 0.5 mile north of, 90 feet southwest of crossing of north-south county road and railroad, 25 feet west of county road, 40 feet southeast of track, 80 feet southwest of crossing signpost marked U.S.G.S.; iron post stamped "DW 3326" B.M. W.P.	3,327.584
Brennan, 2 miles south of, 250 feet southeast of county road crossing, 20 feet southwest of county road, southwest corner of Getchell ranch, 1 foot south of north quarter corner of sec. 14, T. 1 S., R. 8 E.; iron post stamped "DW 3160"	3,161.695
Brennan, 1,300 feet south of section house 215, 75 feet southwest of county road crossing, 80 feet west of signpost marked "Brennan" and scribed U.S.G.S.; iron post stamped "DW 3114" B.M. W.P.	3,115.680

OELRICHS QUADRANGLE.

Bench marks near Hot Springs.

Hot Springs, 4.1 miles north of, east side of junction of Buffalo Gap-Hot Springs road with Hot Springs-Wind Cave road; iron post stamped "DW 3847"	3,848.767
Hot Springs, south entrance to county courthouse, 2.5 feet east of steps in vertical face of wall 2.5 feet above ground; bronze tablet stamped "DW 3462"	3,463.569

Bench marks near Buffalo Gap.

Buffalo Gap, 5 miles east of, southeast corner of NE. ¼ sec. 25, T. 6 S., R. 7 E.; iron post stamped "DW 3221"	3,222.095
Buffalo Gap, 120 feet east of railroad ticket office, 150 feet north of wagon road along south side of sec. 29, T. 6 S., R. 7 E.; iron post stamped "DW 3258"	3,259.585

Hot Springs via Chicago & Northwestern Ry. to Buffalo Gap.

	Feet.
Hot Springs, county courthouse, south entrance, 2.5 feet east of steps, 2.5 feet above ground, in vertical face of wall; bronze tablet marked "DW 3462"	3,463.569
Hot Springs, in front of union station; top of rail	3,444.8
Hot Springs, in front of Chicago & Northwestern Ry. station; top of rail	3,429.2
Hot Springs, 2.3 miles southeast of, 100 feet southwest of track, 300 feet south of bridge, H. S. 23, 150 feet southwest of wagon road, in northeast end of sandstone rock 20 by 10 feet and 4 feet high; copper bolt stamped "DW 3313"	3,314.750
Evans quarry, 450 feet north of post office, 200 feet north of falls of Fall River, 550 feet east of bridge, H. S. 17, 50 feet north of and about 15 feet above track, in irregular sloping rock 10 by 3 feet, 3 feet high, 2 feet south of north end; copper bolt stamped "DW 3225"	3,226.529
Evans quarry, 1.8 miles northeast of, 40 feet northwest of bridge, H. S. 15, 15 feet southwest of telegraph pole, 2 feet south of rock mound, on top of small rock 2 by 1 foot, 1 foot out of ground; chisel mark	3,341.08
Buffalo Gap, 5 miles southwest of, 1,000 feet southwest of section house, 60 feet west of county road crossing, 25 feet southeast of northeast end of snow fence; iron post stamped "DW 3315"	3,316.702
Buffalo Gap, 2 miles southwest of, 290 feet west of county road crossing, 30 feet south of county road, 1.5 feet south of stone marking northwest corner of T. 7 S., R 7 E.; iron post stamped "DW 3410"	3,411.717
Buffalo Gap, in front of station; top of rail, main track	3,258.8
Buffalo Gap, 120 feet east of station ticket office, 150 feet north of wagon road running along south side of sec. 29, T. 6 S., R. 7 E.; iron post stamped "DW 3258"	3,259.585

RAPID QUADRANGLE.

Brennan along Chicago & Northwestern Ry. via Rapid to Sturgis.

Rapid, 3 miles southeast of, sec. 23, T. 1 N., R. 8 E., 1,200 feet east of northwest corner and 30 feet south of north line, 50 feet west of track, 40 feet east of angle in county road; iron post stamped "DW 3218"	3,219.650
Rapid, in front of ticket office; top of rail, main track	3,199.6
Rapid, courthouse yard, 80 feet southwest of southwest corner of courthouse, in center of top of United States Geological Survey astronomic pier; bronze tablet stamped "DW 3228." (Center of plate carefully centered over original cross cut in pier)	3,230.144
Rapid, 3 miles west of, 40 feet southeast of crossing of Rapid-Rochford wagon road, 400 feet east of section house 17; spike in west side of cottonwood tree, 6 inches above ground	3,267.85
Rapid, 5.2 miles northwest of, 65 feet southwest of crossing of Rapid and Blackhawk county road, 50 feet west of track, 80 feet south of crossing, signpost scribed (U. S. G. S.) (B. M., W. P.) 4 feet north of fence corner post; iron post stamped "DW 3457"	3,458.786
Blackhawk, in front of ticket office; top of rail	3,494.9

	Feet.
Blackhawk, 100 feet northwest of station, in west corner of yard on northwest side of building; iron post stamped "DW 3491"	3,492.695
Blackhawk, 2.4 miles northwest of, top of divide between Blackhawk and Piedmont, 90 feet east of county road crossing, 50 feet northeast of track, 25 feet south of county road along east and west section line, 1,150 feet east of northwest corner of sec. 31, T. 3 N., R. 7 E.; iron post stamped "DW 3622"	3,623.741
Piedmont, 1,400 feet southeast of station, southwest end stone culvert, H 238 northwest side of stream, in top of wing wall 1 foot below top of coping stone, 140 feet northeast of telegraph pole marked (U. S. G. S.); bronze tablet stamped "DW 3460" (B. M., W. P.)	3,461.805
Tilford, 2 miles southeast of, about 75 feet northwest of point where Elk Creek wagon road crosses railroad track, 0.25 mile east of mouth of Elk Creek canyon, 150 feet northwest of junction of Elk Creek wagon road with Sturgis-Rapid road; iron post stamped "DW 3565"	3,566.453
Tilford, in front of station; top of rail	3,581.2
Tilford, 2.25 miles northwest of, 45 feet northeast of railroad crossing, on east side of Sturgis-Rapid wagon road; iron post stamped "DW 3693"	3,694.911
Sturgis, 5.5 miles southeast of, about 500 feet southeast of Beaver siding mile board, on west end of south cap of bridge H 256; top of iron driftbolt	3,665.14
Sturgis, 4.5 miles southeast of, 960 feet southeast of switch at Myers siding, 50 feet north of track, 100 feet south of Sturgis-Rapid wagon road; iron post stamped "DW 3622"	3,623.503
Myers siding, at switch; top of rail	3,618.3
Sturgis, 2.8 miles southeast of, top of west end of north cap of bridge H 264, under which Sturgis-Rapid wagon road passes; iron driftbolt	3,634.43

Bench mark at Pactola.

Pactola, junction of road from Rapid with roads from Hill City and Silver City, 3 feet south of corner 15, mineral claim 891; iron post stamped "DW 4459"	4,460.343

Riley ranch to McDonald ranch.

Riley ranch, on Bogus Jim Creek, 2,000 feet northwest of, 10 feet southeast of road from Merritt, center of top of rock 8 by 7 by 2 feet; pine witness trees marked "U.S.G.S. B.M. W.T.," one 24 inches in diameter northeast 75 feet, one 12 inches in diameter north 75 feet, one 18 inches in diameter northwest 30 feet; copper bolt stamped "DW 4801"	4,802.333
Jim Creek, 1,500 feet northeast of mouth, 190 feet north of highway bridge over Boxelder Creek, in east corner of flat rock 15 by 25 by 4 feet; pine witness trees marked "U.S.G.S. B.M. W.T.," one 18 inches in diameter southwest 36 feet, one 15 inches in diameter northwest 36 feet, one 18 inches in diameter northeast 20 feet; bronze tablet stamped "DW 4413"	4,414.286
Estes ranch, 1.5 miles southeast of, 1,800 feet northwest of Elliott's sawmill at west end of highway bridge over Boxelder Creek; spike in root east side of 2-foot pine tree	4,458.83

	Feet.
Estes ranch, 150 feet northwest of dwelling, 12 feet northeast of country road up Boxelder Creek, 30 feet northwest of junction with road running down Estes Creek; spike in south root of 18-inch pine	4,564.81
McDonald ranch, 575 feet northwest of, 15 feet west of county road up Boxelder Creek at junction with private road from ranch; witness trees marked "U.S.G.S. B.M. W.T.," one 18 inches in diameter north 70 feet, one 18 inches in diameter southeast 20 feet, one 12 inches in diameter southwest 45 feet; iron post stamped "DW 4614"	4,615.241

Pactola to Rockerville.

Pactola, junction of road from Rapid with roads from Hill City and Silver City, 3 feet south of corner 15, M. C. 891; iron post stamped "DW 4459"	4,460.343
Harvey ranch, 800 feet north of, on top of divide, east side of road; iron post stamped "DW 5021"	5,022.516
Wetzell ranch, 2 miles south of, 2.5 miles north of intersection of Rapid, Pactola, and Sheridan roads, 30 feet east of road on top of divide; iron post stamped "DW 5042"	5,043.543
Wetzell ranch, 3 miles south of, 1.5 miles north of intersection of Rapid, Pactola, and Sheridan roads, on top of ridge 25 feet east of road; iron post stamped "DW 4864"	4,865.368

SUNDANCE QUADRANGLE.

Bench mark on McQuaig road.

McQuaig road, 3.7 miles west of intersection with Cheyenne-Deadwood stage road, 15 feet south of road fork; iron post stamped "DW 6539"	6,540.563

Bench marks near Pratt ranch.

Pratt ranch (Bear Gulch), 1,000 feet east of, 45 feet south of road, on north bank of Potato Gulch, in quartzite cliff; aluminum tablet stamped "DW 5836"	5,836.260
Pratt ranch, 1 mile northeast of; wire nail in root of 15-inch pine tree north of road	5,845.86

Belle Fourche and Empire 30′ Quadrangles.

BUTTE, LAWRENCE, AND MEADE COUNTIES.

The elevations in this list were originally based on a bronze tablet stamped "4543," set in the city hall building at Deadwood in 1897, the elevation of which is now accepted as 4,544.872 feet above mean sea level. In 1908 the Coast and Geodetic Survey precise line redetermined United States Geological Survey bench marks near Edgemont, thus furnishing a more reliable connection with mean sea level. A correction of +1.4 feet obtained by computation in 1911 has been applied to all elevations in this list.

The leveling in the Belle Fourche quadrangle was done in 1903 and 1904 by Chester Irvine, and in 1904 by M. S. Bright and C. H.

Birdseye; that in the Empire quadrangle was done in 1904 by Chester Irvine and H. M. Hadley, and in 1910 by H. L. Caldwell. The leveling followed section lines almost to the exclusion of the few roads in this area.

BELLE FOURCHE 30' QUADRANGLE.

Point 900 feet east and 2,400 feet north of southwest corner of sec. 21, T. 9 N., R. 4 E., northeast to northwest corner of same section, thence north 4 miles to northwest corner of sec. 33, T. 10 N., R. 4 E., thence east to northwest corner of sec. 36 and south 4.8 miles to point 0.2 mile south of quarter corner between secs. 23 and 24, T. 9 N., R. 4 E.

	Feet.
T. 9 N., R. 4 E., 45 feet southest of northwest stone at corner of sec. 9; iron post stamped "2880 DW"	2, 881. 368
T. 10 N., R. 4 E., northwest corner of sec. 33; iron post stamped "2891 DW"	2, 892. 317
T. 10 N., R. 4 E., northwest corner of sec. 35; iron post stamped "2920 DW"	2, 921. 438
T. 9 N., R. 4 E., northwest corner of sec. 1; iron post stamped "2872 DW"	2, 873. 327
T. 9 N., R. 4 E., northwest corner of sec. 13; iron post stamped "2877 DW"	2, 878. 407
T. 9 N., R. 4 E., 0.2 mile south of quarter corner between secs. 23 and 24; iron post stamped "2865 DW"	2, 866. 257

Northwest corner of sec. 16, T. 9 N., R. 4 E., west 1 mile, north 2 miles, east 2 miles, thence south 1 mile to northwest corner of sec. 33, T. 10 N., R. 4 E.

T. 9 N., R. 4 E., triangulation station No. 18, about 1,200 feet southwest of northwest corner of sec. 17; iron post stamped "3041 DW"	3, 042. 560
Tps. 9 and 10, Rs. 3 and 4, corner of; iron post stamped "2925 DW"	2, 926. 415
T. 10 N., R. 4 E., 30 feet south of quarter corner between secs. 19 and 30; iron post stamped "2904 DW"	2, 904. 978

Northwest corner of sec. 13, T. 9 N., R. 4 E., east 2 miles, south 1 mile, east 1 mile, and south 2 miles to point 400 feet west of northwest corner of sec., 33, T. 9 N., R. 5 E.

T. 9 N., R. 5 E., northwest corner of sec. 20; iron post stamped "2871 DW"	2, 872. 018
T. 9 N., R. 5 E., 400 feet west of northwest corner of sec. 33; iron post stamped "2981 DW"	2, 982. 602

Point 1,100 feet south of quarter corner between secs. 23 and 24, T. 9 N., R. 4 E., south 2 miles, east 1 mile, and south 1 mile, thence east 3 miles and north 0.5 mile to quarter corner between secs. 3 and 4, T. 8 N., R. 5 E., thence north 6.5 miles, west 1 mile, south 1 mile, west 2 miles, north 1 mile, and west 1 mile to northwest corner of sec. 1, T. 9 N., R. 4 E.

T. 9 N., R. 4 E., southeast corner of sec. 36; iron post stamped "2874 DW" (jog of 65 feet in north and south lines)	2, 875. 566
T. 8 N., R. 5 E., 35 feet southwest of northwest corner of sec. 8; iron post stamped "2876 DW"	2, 877. 202
T. 8 N., R. 5 E., quarter corner between secs. 3 and 4, about 400 feet south of Owl Creek bridge; iron post stamped "2821 DW"	2, 821. 760
T. 9 N., R. 5 E., 25 feet west of northwest corner of sec. 34; iron post stamped "2854 DW"	2, 855. 594
T. 9 N., R. 5 E., 5 feet northeast of fence at northwest corner of sec. 22, west side of lane; iron post stamped "2826 DW"	2, 826. 976

	Feet.
T. 9 N., R. 5 E., 3 feet east of northwest corner of sec. 10; iron post stamped "2902 DW"	2,903.838
Tps. 9 and 10 N., R. 5 E., northwest corner of sec. 4; iron post stamped "2858 DW"	2,859.548
T. 9 N., R. 5 E., northwest corner of sec. 8; iron post stamped "2871 DW"	2,872.434

Northwest corner of sec. 30, T. 12 N., R. 5 E., south 2 miles, west 3 miles, and south 7 miles to northwest corner of sec. 10, T. 10 N., R. 9 E.

T. 12 N., R. 5 E., northwest corner of sec. 30; iron post stamped "3164 DW"	3,165.446
T. 11 N., R. 4 E., northwest corner of sec. 1; iron post stamped "3194 DW"	3,195.276
T. 11 N., R. 4 E., northwest corner of sec. 10; iron post stamped "3196 DW"	3,197.554
T. 11 N., R. 4 E., northwest corner of sec. 27; iron post stamped "3044 DW"	3,045.498
T. 10 N., R. 4 E., northwest corner of sec. 10; iron post stamped "3028½ DW"	3,029.948

Corner of Tps. 9 and 10 N., Rs. 3 and 4 E., west 2 miles, north 1 mile, and west 1 mile, thence north 12 miles to northwest corner of sec. 34, T. 12 N., R. 3 E., thence west 6 miles to northwest corner of sec. 34, T. 12 N., R. 2 E., thence south 14 miles to northwest corner of sec. 10, T. 9 N., R. 2 E., thence east 1 mile and south 3 miles to northwest corner of sec. 26, T. 9 N., R. 2 E.

T. 10 N., R. 3 E., northwest corner of sec. 35; iron post stamped "3054 DW"	3,055.337
T. 10 N., R. 3 E., northwest corner of sec. 22; iron post stamped "2956 DW"	2,967.331
Ts. 10 and 11 N., R. 3 E., northwest corner of sec. 3; iron post stamped "2948 DW"	2,949.3
T. 11 N., R. 3 E., northwest corner of sec. 22; iron post stamped "3043 DW"	3,044.273
T. 11 N., R. 3 E., near northwest corner of sec. 3 (no corner post found), at heap of rocks; iron post stamped "3117 DW"	3,118.369
T. 12 N., R. 3 E., 30 feet northwest of northwest corner of sec. 32; iron post stamped "3126 DW"	3,127.567
T. 12 N., R. 2 E., quarter corner between secs. 26 and 35; iron post stamped "3114 DW"	3,115.226
T. 11 N., R. 2 E., northwest corner of sec. 10; iron post stamped "3104 DW"	3,105.344
T. 11 N., R. 2 E., 800 feet west and 180 feet north of northwest corner of sec. 27, on summit of divide between Owl and Indian creeks; iron post stamped "3297 DW"	3,298.360
T. 10 N., R. 2 E., 30 feet southwest of northwest corner of sec. 10; iron post stamped "3034 DW"	3,035.462
T. 10 N., R. 2 E., between corner pits at northwest corner of sec. 27; iron post stamped "3114 DW"	3,115.341
T. 9 N., R. 2 E., 1 foot west of northwest corner of sec 11; iron post stamped "3250 DW"	3,251.297
T. 9 N., R. 2 E., at corner of secs 22, 23, 26, and 27; iron post stamped "3076 DW"	3,077.608

Northwest corner of sec. 34, T. 12 N., R. 4 E., west 6 miles, thence south 18 miles to northwest corner of sec. 3, T. 9 N., R. 1 E., thence east 1 mile, south 1 mile, and east 5 miles to northwest corner of sec. 10, T. 9 N., R. 2 E.

	Feet.
T. 12 N., R. 2 E., northwest corner of sec. 31; iron post stamped "3130 DW"	3,131.300
T. 12 N., R. 1 E., northwest corner of sec. 34 (no corner found), in small draw 10 feet west of Alzada road; iron post stamped "3238 DW"	3,239.408
T. 11 N., R. 1 E., northwest corner of sec. 15; iron post stamped "3123 DW"	3,124.359
T. 11 N., R. 1 E., 450 feet north of northwest corner of sec. 3, T. 10 N., R. 2 E. (no corner post found), 150 feet northwest of clump of three trees, in small creek bed; iron post stamped "3187 DW"	3,188.373
T. 10 N., R. 1 E., between corner pits northwest corner of sec. 22; iron post stamped "3322 DW"	3,323.507
Tps. 9 and 10 N., R. 1 E., 1 foot west of northwest corner of sec. 2; iron post stamped "3181 DW"	3,182.571
T. 9 N., Rs. 1 and 2 E., 3 feet west of northwest corner of sec. 7; iron post stamped "3126 DW"	3,127.491

Spearfish along county road to Belle Fourche, thence to The Forks.

T. 7 N., R. 2 E., 1,200 feet south of quarter corner between secs. 34 and 27; iron post stamped "3601 DW 1903"	3,602.274
T. 7 N., R 2 E., 1,200 feet north of quarter corner between secs. 10 and 15; iron post stamped "3343 DW 1903"	3,344.620
Willow Creek bridge, 400 feet south of, at fence corner, 40 feet north of crossing of roads; iron post stamped "3360 DW 1903"	3,161.384
T. 8 N., R. 1 E., 300 feet east of stone at corner of secs. 11, 12, 13, and 14, forks of road; iron post stamped "3373 DW 1903"	3,374.132
Joost schoolhouse, 100 feet north of; iron post stamped "3274 DW 1903"	3,275.390
The Forks (Robinson ranch), at junction of old Miles City stage road with road from Aladdin (coal bank), in sandstone rock 6 by 8 inches, 17 inches above ground; aluminum tablet stamped "3398 DW"	3,399.435

Belle Fourche along Three V ranch road to Middle Creek Butte.

Belle Fourche, Butte County jail, northeast corner of; iron post stamped "3036 DW 1903"	3,037.678
Belle Fourche, Butte County courthouse, southeast corner of yard, in stone; azimuth tablet stamped "3011 DW"	3,012.638
Belle Fourche, 2.9 miles west of, 10 feet south of road, on rise near fence; iron post stamped "3098 DW 1903"	3,099.299
T. 9 N., R. 1 E., NE ¼ sec. 22, 30 feet south of wagon road; iron post stamped "3204 DW 1903"	3,205.187
Three V ranch, 2.5 miles north of; iron post	3,180.091

Belle Fourche along county road via Richardson ranch and Giles Crossing to Belle Fourche.

T. 9 N., R. 2 E., corner of secs. 22, 23, 26, and 27; iron post stamped "3076 DW 1903"	3,077.608
T. 9 N., R. 3 E., 0.2 mile north of quarter corner between secs. 29 and 32; iron post stamped "3029 DW 1903"	3,029.933

	Feet.
T. 8 N., R. 3 E., just south of northwest corner of sec. 4; iron post stamped "3004 DW 1903"	3,005.101
T. 8 N., R. 3 E., quarter corner between secs. 7 and 18; iron post stamped "3187 DW 1903"	3,188.404

Belle Fourche along railroad to St. Onge, thence along county road to Centennial Prairie.

T. 8 N., R. 3 E., corner of secs. 26, 30, 31, and 36; iron post stamped "3149 DW 1903"	3,150.238
T. 7 N., R. 3 E., 0.2 mile north of and 2,300 feet west of southeast corner of sec. 9; iron post stamped "3314 DW 1903"	3,318.366
St. Onge, 200 feet west of station, 2,000 feet east of southwest corner of sec. 23, T. 7 N., R. 3 E.; iron post stamped "3428 DW 1903"	3,429.213
T. 6 N., R. 3 E., corner of secs 2, 3, 10, and 11; iron post stamped "3614 DW 1903"	3,615.306

Belle Fourche along county road via Snoma and Big Bottom to St. Onge.

T. 8 N., R. 3 E., 900 feet north of corner of secs. 14, 15, 22, and 23; iron post stamped "3097 DW 1903"	3,098.534
T. 8 N., R. 4 E., quarter corner between secs. 17 and 20; iron post stamped "2920 DW 1903"	2,921.430
T. 8 N., R. 4 E., corner of secs. 13, 14, 23, and 24; iron post stamped "2940 DW 1903"	2,941.254
T. 8 N., R. 5 E., corner of secs. 15, 16, 21, and 22; iron post stamped "2886 DW 1903"	2,887.354
T. 7. N., R. 5 E., 1,100 feet east of corner of secs. 4, 5, 8, and 9; iron post stamped "2984 DW 1903"	2,985.433
T. 7 N., R. 5 E., center of sec. 29; iron post stamped "3132 DW 1903"	3,133.349
T. 7 N., R. 5 E., 350 feet east of northwest corner of sec. 19; iron post stamped "3149 DW 1903"	3,150.247
T. 7 N., R. 4 E., 200 feet west of quarter corner between secs. 31 and 32; iron post stamped "3664 DW 1903"	3,665.369

Giles ranch along county road and across country via Owl Creek Bridge to corner of secs. 15, 16, 21, and 22, T. 8 N., R. 5 E.

T. 9 N., R. 3 E., corner of secs. 26, 27, 34, and 36; iron post stamped "2983 DW 1903"	2,984.273
T. 9 N., R. 4 E., 400 feet north and 1,600 feet west of southeast corner of sec. 30; iron post stamped "2960 DW 1903"	2,961.327
T. 9 N., R. 4 E., 900 feet east and 2,400 feet north of southwest corner of sec. 21; iron post stamped "2933 DW 1903"	2,934.323
T. 9 N., R. 5 E., 1,600 feet north of corner of secs. 23, 24, 25, and 26; iron post stamped "2865 DW 1903"	2,866.257
T. 9 N., R. 5 E., 500 feet west of corner of secs. 28, 29, 32, and 33; iron post stamped "2981 DW 1903"	2,982.602
T. 8 N., R. 5 E., 2,100 feet north of corner of secs. 3, 4, 9, and 10; iron post stamped "2821 DW 1903"	2,821.760

EMPIRE QUADRANGLE.

Northwest corner of sec. 22, T. 8 N., R. 5 E., east 1 mile, south 1 mile, east 1 mile, south one-half mile, east 1 mile, and south one-half mile to northwest corner of sec. 31, T. 8 N., R. 6 E., thence east 10 miles to northwest corner of sec. 35, T. 8 N., R. 7 E., thence north 2 miles, east 1 mile, north 1 mile, and west 10 miles to northwest corner of sec. 13, T. 8 N., R. 5 E., thence north 1 mile, west 2 miles, and north one-half mile to section line 2,100 feet north of northwest corner of sec. 10, T. 8 N., R. 5 E.

	Feet.
T. 8 N., R. 5 E., 30 feet northeast of northwest corner of sec. 25; iron post stamped "2815 DW"	2,816.402
T. 8 N., R. 6 E., 40 feet northwest of northwest corner of sec. 32; iron post stamped "2788 DW"	2,789.278
T. 8 N., R. 6 E., 40 feet southwest of northwest corner of sec. 35; iron post stamped "2812 DW"	2,809.497
T. 8 N., Rs. 6 and 7 E., 30 feet southwest of northwest corner of sec. 31; iron post stamped "2783 DW"	2,784.331
T. 8 N., R. 7 E., 50 feet southeast of northwest corner of sec. 33; iron post stamped "2710 DW"	2,711.271
T. 8 N., R. 7 E., 40 feet southeast of northwest corner of sec. 35; iron post stamped "2679 DW"	2,679.125
T. 8 N., R. 7 E., northwest corner of sec. 23; iron post stamped "2777 DW"	2,777.456
T. 8 N., R. 7 E., near northwest corner of sec. 16, at fence corner south of road; iron post stamped "2726 DW"	2,726.126
T. 8 N., Rs. 6 and 7 E., 40 feet southeast of northwest corner of sec. 18; iron post stamped "2728 DW"	2,728.211
T. 8 N., R. 6 E., 40 feet southeast of northwest corner of sec. 14; iron post stamped "2751 DW"	2,751.336
T. 8 N., R. 6 E., 50 feet southwest of southeast corner of sec. 7; iron post stamped "2903 DW"	2,904.307
T. 8 N., R. 5 E., at quarter corner between secs. 11 and 12; iron post stamped "2819 DW"	2,819.210
T. 8 N., R. 5 E., 2,100 feet north of northwest corner of sec. 10; iron post stamped "2820 DW"	2,821.760

Horse Creek Bridge at Steager ranch east 2 miles and south 1 mile, thence east 9 miles to northwest corner of sec. 33, T. 9 N., R. 7 E., thence south 3 miles to northwest corner of sec. 16, T. 8 N., R. 7 E.

T. 9 N., R. 5 E., southeast corner of sec. 23; iron post stamped "2903 DW"	2,904.385
T. 9 N., R. 6 E., quarter corner between secs. 30 and 31; iron post stamped "2857 DW"	2,858.484
T. 9 N., R. 6 E., quarter corner between secs. 28 and 33; iron post stamped "2810 DW"	2,811.492
T. 9 N., R. 6 E., southeast corner of sec. 26; iron post stamped "2805 DW"	2,806.312
T. 9 N., R. 7 E., southeast corner of sec. 29; iron post stamped "2840 DW"	2,841.216

Northwest corner of sec. 15, T. 9 N., R. 5 E., east 3 miles, north 2 miles, east 2 miles, and south and east 5 miles to quarter corner between secs. 28 and 33, T. 9 N., R. 6 E.

T. 9 N., R. 6 E., northwest corner of sec. 18; iron post stamped "2850 DW"	2,851.344

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	Feet.
Tps. 9 and 10 N., Rs. 5 and 6 E., corner of; iron post stamped "2898 DW 1904"	2,899.278
T. 9 N., R. 6 E., northwest corner of sec. 4; iron post stamped "2909 DW"	2,910.357
T. 9 N., R. 6 E., 30 feet south of northwest corner of sec. 16; iron post stamped "2871 DW"	2,872.267

Northwest corner of sec. 16, T. 9 N., R. 6 E., east 6 miles, north 1 mile, and east 2 miles to northwest corner of sec. 11, T. 9 N., R. 7 E., thence south 1 mile, west 1 mile, south 1 mile, west 1 mile, and south 2 miles to northwest corner of sec. 33, T. 9 N., R. 7 E.

T. 9 N., R. 6 E., 380 feet north of northwest corner of sec. 13; iron post stamped "2897 DW"	2,898.294
T. 9 N., R. 7 E., northwest corner of sec. 17; iron post stamped "2776 DW"	2,777.072
T. 9 N., R. 7 E., northwest corner of sec. 10; iron post stamped "2902 DW"	2,903.489
T. 9 N., R. 7 E., northwest corner of sec. 14; iron post stamped "2908 DW"	2,909.272
T. 9 N., R. 7 E., northwest corner of sec. 21; iron post stamped "2873 DW"	2,874.224

Point 40 feet southwest of northwest corner of sec. 35, T. 8 N., R. 6 E, south 3 miles, west 6 miles, south 0.5 mile, east 1 mile, south 1.5 miles, east 1 mile, and south 2 miles to corner of Tps. 6 and 7 N., Rs. 5 and 6 E., thence east 8 miles, north 4 miles, east 1 mile, north 2 miles, and northwest 1 mile to point 50 feet southeast of northwest corner of sec. 33, T. 8 N., R. 7 E.

T. 7 N., R. 6 E., northwest corner of sec. 14; iron post stamped "2890 DW"	2,891.391
T. 7 N., R. 6 E., 300 feet east of northwest corner of sec. 17; iron post stamped "3025 DW"	3,026.374
T. 7 N., R. 5 E., northwest corner of sec. 14; iron post stamped "2908 DW"	2,909.401
T. 7 N., R. 5 E., northwest corner of sec. 25; iron post stamped "2934 DW"	2,935.383
T. 6 N., R. 6 E., northwest corner of sec. 6; iron post stamped "3037 DW"	3,038.414
T. 6 N., R. 6 E., northwest corner of sec. 3; iron post stamped "3068 DW"	3,069.419
Tps. 6 and 7 N., Rs. 6 and 7 E., corner of; iron post stamped "2983 DW"	2,984.467
T. 7 N., R. 7 E., northwest corner of sec. 33; iron post stamped "2942 DW"	2,943.454
T. 7 N., R. 7 E., northwest corner of sec. 16; iron post stamped "2819 DW"	2,820.470

Northwest corner of sec. 10, T. 9 N., R. 7 E., north 15 miles to northwest corner of sec. 27, T. 12 N., R. 7 E., thence east 6 miles to northwest corner of sec. 27, T. 12 N., R. 6 E., thence south 14 miles and west 1 mile to northwest corner of sec. 4, T. 9 N., R. 6 E.

T. 10 N., R. 7 E., northwest corner of sec. 27; iron post stamped "2935 DW"	2,936.250
T. 10 N., R. 7 E., northwest corner of sec. 10; iron post stamped "3093 DW"	3,094.135

	Feet.
T. 11 N., R. 7 E., northwest corner of sec. 27; iron post stamped "3004 DW"	3,005.204
T. 11 N., R. 7 E., northwest corner of sec. 10; iron post stamped "2927 DW"	2,928.280
T. 12 N., R. 7 E., northwest corner of sec. 27; iron post stamped "2957 DW"	2,958.437
T. 12 N., R. 7 E., northwest corner of sec. 30; iron post stamped "2979 DW"	2,980.303
T. 12 N., R. 6 E., nothwest corner of sec. 27; iron post stamped "3045 DW"	3,046.299
T. 11 N., R. 6 E., northwest corner of sec. 10; iron post stamped "3063 DW"	3,065.337
T. 11 N., R. 6 E., northwest corner of sec. 27; iron post stamped "2986 DW"	2,987.277
T. 10 N., R. 6 E., northwest corner of sec. 10; iron post stamped "2943 DW"	2,944.372
T. 10 N., R. 6 E., northwest corner of sec. 27; iron post stamped "2929 DW"	2,930.330
T. 9 N., R. 6 E., NW. ¼ sec. 3, Dry triangulation station; iron post stamped "3006 DW"	3,007.223

Northwest corner of sec. 10, T. 9 N., R. 5 E., north along section lines to northwest corner of sec. 30, T. 12 N., Rs. 4 and 5 E.

T. 10 N., R. 5 E., northwest corner of sec. 27; iron post stamped "2942 DW"	2,943.217
T. 10 N., R. 5 E., northwest corner of sec. 10; iron post stamped "2976 DW"	2,976.314
T. 11 N., R. 5 E., northwest corner of sec. 27; iron post stamped "3160 DW"	3,161.226
T. 11 N., R. 5 E., northwest corner of sec. 10; iron post stamped "3049 DW"	3,050.414
T. 12 N., R. 5 E., northwest corner of sec. 27; iron post stamped "3169 DW"	3,170.282

Northwest corner of sec. 33, T. 7 N., R. 7 E., east along line between Tps. 6 and 7 N., thence north along line between Rs. 8 and 9, thence west along line between Tps. 11 and 12 N. to northwest corner of sec. 10, T. 11 N., R. 7 E.

NOTE.—The original error of this line was 2.66 feet. The line was adjusted by correcting 2.06 feet of this error between secs. 17 and 18, T. 8 N., R. 9 E., where doubt exists, and the remainder by distribution. Reliance can not be placed on these elevations until they are checked by further field work.

T. 7 N., R. 7 E., northwest corner of sec. 33; iron post stamped "2942"	2,943.454
T. 6 N., R. 7 E., northwest corner of sec. 3; top of corner stone marked "2901"	2,898.03
T. 6 N., R 7 E., northwest corner of sec. 2; top of corner stone marked "2894"	2,891.27
T 6 N., R. 7 E., northwest corner of sec. 1; top of corner stone marked "2839"	2,835.73
T. 6 N., R. 8 E., northwest corner of sec. 6; iron post stamped "2793"	2,789.713
T. 6 N., R. 8 E., northwest corner of sec. 5; top of corner stone marked "2745"	2,742.31

	Feet.
T. 6 N., R. 8 E., 40 feet northwest of iron bridge, on Belle Fourche River; iron post stamped "2555"	2,552.122
T. 7 N., R. 8 E., northwest corner of SW. ¼ sec. 24; top of rock marked "2781"	2,778.08
T. 7 N., R. 9 E., northwest corner of sec. 19; iron post stamped "2761"	2,757.819
T. 7 N., R. 9 E., northwest corner of SW. ¼ sec. 7; top of rock marked "2766"	2,763.10
T. 7 N., R. 9 E., northwest corner of sec. 7, top of corner stone marked "2741"	2,738.16
T. 7 N., R. 9 E., northwest corner of sec. 6; iron post stamped "2733"	2,730.556
T. 8 N., R. 8 E., 600 feet northwest of southeast corner of sec. 36; square cut in top of large rock marked "2774"	2,771.14
T. 8 N., R. 9 E., west side of sec 19, on section line; large rock marked "2752"	2,749.35
T. 8 N., R. 9 E., near center of sec. 18; large rock marked "2788"	2,785.83
T. 8 N., R. 9 E., northwest corner of sec. 17; iron post stamped "2701"	2,700.536
T. 8 N., R. 9 E., northwest corner of SW. ¼ sec. 6; top of rock marked "2745"	2,744.41
T. 8 N., R. 9 E., northwest corner of sec. 6; iron post stamped "2770"	2,769.428
T. 9 N., R. 9 E., on line between secs. 31–36, northwest corner of sec. 31; rock marked "2810"	2,809.40
T. 9 N., R. 9 E., northwest corner of sec. 19; iron post stamped "2851"	2,850.555
T. 9 N., R. 9 E., northwest corner of NE. ¼ sec. 7; top of rock marked "2875"	2,874.57
T. 9 N., R. 9 E., northwest corner of sec. 5; iron post stamped "2818"	2,818.950
T. 10 N., R. 9 E., northwest corner of SE. ¼ sec. 19; top of large rock marked "2905"	2,904.51
T. 10 N., R. 9 E., northwest corner of sec. 19; iron post stamped "2834"	2,833.571
T. 10 N., R. 9 E., on west line of sec. 18; large rock marked "2856"	2,855.20
T. 10 N., R. 9 E., west line of sec. 7, at top of high hill; large rock marked "2871"	2,870.52
T. 10 N., R. 9 E., northwest corner of sec. 7; top of large rock marked "2846"	2,845.41
T. 10 N., R. 9 E., northwest corner of sec. 6; iron post stamped "2876"	2,875.131
T. 11 N., R. 9 E., on west line of sec. 30, 500 feet south northwest of corner of sec. 30; wooden stake marked "2825"	2,825.38
T. 11 N., R. 9 E., northwest corner of sec. 19; iron post stamped "2795"	2,794.286
T. 11 N., R. 9 E., 700 feet south and 300 feet west of northwest corner of sec. 6; top of rock marked "2873"	2,872.35
T. 11 N., R. 9 E., 700 feet south and 300 feet west of northwest corner of sec. 6, in large rock; tablet stamped "2874"	2,873.783
T. 11 N., R. 8 E., northwest corner of sec. 3; iron post stamped "2910"	2,909.445
T. 11 N., R. 8 E., northwest corner of sec. 6, at top of hill north of trail; iron post stamped "2926"	2,925.58

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 473

RESULTS OF SPIRIT LEVELING IN KANSAS AND NEBRASKA

1896 TO 1909, INCLUSIVE

R. B. MARSHALL, CHIEF GEOGRAPHER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1911

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A, Tablet used in cooperating States. The State name is inserted at *G*.
B and *D*, Copper temporary b... ...onsisting of a nail and copper washer
A, *C*, and *E*, Tablets for s... ...ictures.
F, Iron post used where th

RESULTS OF SPIRIT LEVELING IN KANSAS AND NEBRASKA, 1896 TO 1909, INCLUSIVE.

R. B. MARSHALL, Chief Geographer.

INTRODUCTION.

Scope of the work.—All results of spirit leveling in Kansas and Nebraska previously published by the United States Geological Survey and all the results of later work are included in this report, rearranged by quadrangles. Elevations are based on heights of bench marks along precise-level lines of the Coast and Geodetic Survey and of the Missouri River Commission, as adjusted in 1907. The elevation of bench marks in the western part of both States are based on railroad data, and are, therefore, only approximate.

Personnel.—The field work previous to 1903 was done under the general direction of J. H. Renshawe, geographer; that for 1903 to 1906, inclusive, under H. M. Wilson, geographer; and the later work under W. H. Herron, geographer. The names of the various levelmen are given in the introduction to each list. The office work of computation, adjustment, and preparation of lists was done mainly by S. S. Gannett, geographer, and D. H. Baldwin, topographer, and since 1907 under the general direction of E. M. Douglas, geographer.

Classification.—No precise leveling has been done by the United States Geological Survey in Kansas and Nebraska. For primary lines standard Y levels are used; lines are run in circuits or are closed on precise lines, with an allowable closing error in feet represented by $0.05\sqrt{D}$, in which D is the length of the circuit in miles, sufficient care being given to the work to maintain this standard. For levels of this class careful office adjustments are made, the circuit errors being distributed over the lines.

Bench marks.—The standard bench marks are of two forms. The first form is a circular bronze or aluminum tablet (C and E, Pl. I), 3½ inches in diameter and one-quarter inch thick, having a 3-inch stem, which is cemented in a drill hole in solid rock in the wall of some public building, a bridge abutment, or other substantial masonry structure. The second form (F, Pl. I), used where masonry or rock is not available, consists of a hollow wrought-iron post 3½ inches in outer diameter and 4 feet in length. The bottom is spread out to a width of 10 inches in order to give a firm bearing on the earth. A bronze or aluminum-bronze cap is riveted over the top of the post, which is set about 3 feet in the ground. A third style of bench mark with abbreviated lettering (B and D, Pl. I) is used for unimportant points. This consists of a special copper nail 1½ inches in length driven through a copper washer seven-eighths inch in diameter. The tablets, as well as the caps on the iron posts are appropriately lettered, and cooperation by States is indicated by the addition of the State name (G, Pl. I).

The numbers stamped on the bench marks described in the following pages represent the elevations to the nearest foot as determined by the levelman. These numbers are stamped with $\frac{3}{16}$-inch steel dies on the tablets or post caps, to the left of the word "feet." The office adjustment of the notes and the reduction to mean sea level datum may so change some of the figures that the original markings are 1 or 2 feet in error. It is assumed that engineers and others who have occasion to use the bench-mark elevations will apply to the Director of the United States Geological Survey, at Washington, D. C., for the adjusted values, and will use the markings as identification numbers only.

Datum.—All United States Geological Survey elevations are referred to mean sea level, which is the level that the sea would assume if the influence of winds and tides were eliminated. This level is not the elevation determined from the mean of the highest and the lowest tides, nor is it the half sum of the mean of all the high tides and the mean of all the low tides, which is called the half-tide level. *Mean sea level is the average height of the water, all stages of the tide being considered.* It is determined from observations made by means of tidal gages placed at stations where local conditions, such as long, narrow bays, rivers, and like features, will not affect the height of the water. To obtain even approximately correct results these observations must extend over at least one lunar month, and if accuracy is desired they must extend over several years. At ocean stations the half-tide level and the mean sea level usually differ but little. It is assumed that there is no defference between the mean sea level as determined from observations in the Atlantic Ocean, the Gulf of Mexico, or the Pacific Ocean.

The connection with tidal stations for bench marks in certain areas that lie at some distance from the sea coast is still uncertain, and this fact is indicated by the addition of a letter or word to the right of the word "datum" on tablets or posts. For such areas corrections for published results will be made from time to time as the precise-level lines of the United States Geological Survey or other Government organizations are extended.

Topographic maps.—Maps of the following quadrangles wholly or partly in Kansas and Nebraska have been published by the United States Geological Survey up to May 1, 1911. They may be obtained, except as noted, for 5 cents each or $3 a hundred, on application to the Director of the Survey at Washington, D. C.

KANSAS.

Abilene.
Albany (Colo.-Kans.).
Anthony.
Arapahoe (Nebr.-Kans.).
Ashland.[1]
Atchison (Kans.-Mo.).
Beloit.
Burden.
Burlingame.
Burlington.
Caldwell.
Cheyenne Wells (Colo.-Kans.).
Clay Center.
Coldwater.
Concordia.
Cottonwood Falls.
Dodge.
Eldorado.
Ellis.
Ellsworth.
Emporia.
Eskridge.
Eureka.
Fort Scott (Kans.-Mo.).
Fredonia.
Garden.
Garnett.
Granada (Colo.-Kans.).
Great Bend.
Hays.
Hebron (Nebr.-Kans.).
Hiawatha.
Hill.
Holdrege (Nebr.-Kans.).
Hutchinson.
Independence.
Iola.
Joplin (Kans.-Mo.-Okla.).
Joplin district (Mo.-Kans.-Okla.), double sheet (10 cents).
Junction City.
Kansas City (Kans.-Mo.).
Kingman.
Kinsley.
Lakin.
Larned.
Lawrence.
Leavenworth (Kans.-Mo.).
Lyons.
Mankato.
Marysville.
Meade.
Medicine Lodge.
Minneapolis.
Mound City (Kans.-Mo.).
Ness.
Newton.
Norton.
Olathe (Kans.-Mo.).
Osborne.
Oskaloosa (Kans.-Mo.).
Parkerville.
Parsons.
Phillipsburg.
Plainville.
Pratt.
Red Cloud (Nebr.-Kans.).
Russell.
Salina.
Sedan.
Seneca.
Sitka.[1]
Smith Center.
Spearville.
Superior (Nebr.-Kans.).
Syracuse.
Topeka.
Vilas (Colo.-Kans.).
Wamego.
Washington.
Wellington.
Wichita.
Wyandotte (Okla.-Mo.-Kans.).

[1] Sitka sheet, on scale of 1:62500, has been reduced and forms part of Ashland sheet, on scale of 1:125000.

NEBRASKA.

Arapahoe (Nebr.-Kans.).
Browns Creek.
Camp Clarke.
Chappell.
David City.
Edgemont (S. Dak.-Nebr.).
Elk Point (S. Dak.-Nebr.-Iowa).
Fremont.
Goshen Hole (Wyo.-Nebr.).
Gothenburg.
Grand Island 30'.[1]
*Grand Island 15'.[1]
Hebron (Nebr.-Kans.).
Holdrege (Nebr.-Kans.).
Kearney 30'.[2]
Kearney 15'.[2]
*Kenesaw.[3]
Lexington.
Lincoln.
Loup.
Minden.[3]
Nebraska City (Nebr.-Iowa-Mo.).
North Platte.
Oelrichs (S. Dak.-Nebr.).
Ogalalla.
Omaha and vicinity (Nebr.-Iowa) (10 cents).
Patrick (Wyo.-Nebr.).
Paxton.
Red Cloud (Nebr.-Kans.).
St. Paul.
Scotts Bluff.
Sidney.
Stromsburg.
Superior (Nebr.-Kans.).
Wahoo.
Weeping Water.
Whistle Creek.
Wood River 30'.[3]
*Wood River 15'.[3]
York.

KANSAS.

PRIMARY LEVELING.

Joplin District.

CHEROKEE COUNTY.

The elevations published in the following list are based on bench mark "CIII" of the Coast and Geodetic Survey at Carthage, Mo., at the southwest corner of Main and Limestone streets, a cross cut on the rounded top of a 6 by 6 inch limestone post buried in the ground 2.3 feet west of intersection of the inside lines of sidewalk. The elevation of this bench mark, as corrected by the 1907 adjustment of that survey, is accepted as 942.000 feet above mean sea level.

The leveling was done in 1904 by D. C. Wray.

All bench marks dependent upon this datum are stamped with the letters "CRTHG" in addition to the figures of elevation.

For additional data for the same area see Bulletin 459, "Results of spirit leveling in Missouri."

* Out of print.

[1] Grand Island sheet, on scale of 1:62500, has been reduced and forms part of Grand Island sheet, on scale of 1:125000.

[2] Kearney 15' sheet, on scale of 1:62500, has been reduced and forms part of Kearney 30' sheet, on scale of 1:125000.

[3] Kenesaw, Minden, and Wood River 15' sheets, on scale of 1:62500, have been reduced and form parts of Wood River 30' sheet, on scale of 1:125000.

JOPLIN DISTRICT.

	Feet.
T. 35 S., R. 25 E., northeast corner of sec. 11, 24 feet west of corner stone; iron post stamped "1016 CRTHG"	1,016.027
Galena, west side of Euclid Avenue, between Seventh and Eighth streets, 2 feet north of southeast corner of foundation of schoolhouse; aluminum tablet stamped "976 CRTHG"	976.157
Baxter Springs, 51 feet west of southeast corner of city hall, in third course of stone below water table; aluminum tablet stamped "842 CRTHG"	842.316
T. 33 S., R. 25 E., SE. ¼ sec. 12, 45 feet south of corner stone, at west side of State line road; iron post stamped "914 CRTHG"	913.851
T. 32 S., R. 25 E., northwest corner of sec. 19, 4 feet east of corner fence post, southeast of crossroads; iron post stamped "904 CRTHG"	903.765
T. 33 S., R. 24 E., northeast corner of sec. 1, 40 feet south and 15 feet west of corner stone in center of crossroads; iron post stamped "893 CRTHG".	892.813
T. 34 S., R. 24 E., northeast corner of sec. 1, 40 feet south and 30 feet west of corner stone in center of crossroads; iron post stamped "862 CRTHG".	861.730

Iola and Parsons Quadrangles.

ALLEN, BOURBON, CRAWFORD, LABETTE, AND NEOSHO COUNTIES.

The elevations in the following list are based on an aluminum tablet stamped "968 IOLA" in the northeast corner of Northup's National Bank at Iola, Kans., the elevation of which is accepted as 971.489 feet above mean sea level. The initial point upon which this work depends is the bronze tablet established by the Indian Territory levels in the school building at Chetopa, Kans., the elevation of which as now accepted is 4.850 feet higher than published in Bulletin 175.

The leveling was done in 1902 by Fox Wood.

PARSONS QUADRANGLE.

Chetopa north along Missouri, Kansas & Texas Ry. to Erie, thence along highway to La Harpe. (Double-rodded line.)

	Feet.
Erie, in east wing of courthouse; bronze tablet stamped "892 IOLA"	895.080
T. 26 S., R. 20 E., northeast corner of sec. 31, in north end of stone pier at south end of iron bridge over Big Creek; aluminum tablet stamped "940 IOLA"	943.033
T. 25 S., R. 19 E., southeast corner of sec. 36, in south side of schoolhouse, near corner of sections; bronze tablet stamped "1068 IOLA"	1,071.293
T. 24 S., R. 19 E., southeast corner of sec. 36; iron post stamped "1032 IOLA"	1,035.267

IOLA QUADRANGLE.

Erie along highway east and around Tps. 27 and 28 S., R. 21 E.

T. 29 S., R. 21 E., 0.25 mile east of northwest corner of sec. 6, north side of schoolhouse; bronze tablet stamped "896 IOLA"	899.075
T. 28 S., R. 22 E., 0.25 mile south of northwest corner of sec. 31, east side of road, north end of bridge over Big Walnut Creek, in rock abutment; bronze tablet stamped "897 IOLA"	900.242
T. 27 S., R. 21 E., southeast corner of sec. 36; iron post stamped "952 IOLA"	955.171
Portersville, northeast corner of schoolhouse; aluminum tablet stamped "1008 IOLA"	1,011.130

	Feet.
Savonburg, in west wing of schoolhouse; bronze tablet stamped "1057 IOLA"	1,060.758
T. 27 S., R. 20 E., southeast corner of sec. 36; iron post stamped "1022 IOLA"	1,025.206
T. 27 S., R. 19 E., southeast corner of sec. 36, in northeast corner of church; bronze tablet stamped "1004 IOLA"	1,007.132
T. 26 S., R. 18 E., southeast corner of sec. 36; iron post stamped "997 IOLA"	1,000.496
North Valley, southeast corner of sec. 36, T. 27 S., R. 18 E., in southeast corner of schoolhouse; bronze tablet stamped "909 IOLA"	911.314

Northeast corner of T. 26 S., R. 19 E., west through Humboldt and south along range line between Rs. 17 and 18 E., thence along township line between Tps. 28 and 29 S.

Humboldt, 3 miles east of, northwest corner of Central Avenue schoolhouse; bronze tablet stamped "976 IOLA"	979.612
T. 26 N., R. 18 E., southwest corner of sec. 30, in southwest corner of schoolhouse; aluminum tablet stamped "953 IOLA"	955.823
T. 27 S., R. 17 E., southeast corner of sec. 36; iron post stamped "981 IOLA"	983.909
T. 28 S., R. 17 E., southeast corner of sec. 36; iron post stamped "957 IOLA"	960.138
Urbana, southeast corner of church; aluminum tablet stamped "954 IOLA"	957.304
T. 24 S., R. 20 E., southeast corner of sec. 36; iron post stamped "1091 IOLA"	1,094.358
T. 24 S., R. 21 E., southeast corner of sec. 36; iron post stamped "1062 IOLA"	1,065.993
T. 23 S., R. 21 E., southeast corner of sec. 36; iron post stamped "1043 IOLA"	1,045.707
T. 24 S., R. 20 E., northeast corner of sec. 1, on north side of schoolhouse; bronze tablet stamped "1024 IOLA"	1,027.143
T. 24 S., R. 20 E., sec. 7, northwest corner of schoolhouse; bronze tablet stamped "1059 IOLA"	1,062.041

La Harpe west along railroad and highway and around T. 25 S., Rs. 18 and 19 E.

Iola, in northeast corner of Northup's National Bank; bronze tablet stamped "968 IOLA"	971.489
T. 24 S., R. 17 E., southeast corner of sec. 25; iron post stamped "1010 IOLA"	1,012.742
T. 23 S., R. 18 E., southeast corner of sec. 31; iron post stamped "1050 IOLA"	1,052.860
T. 23 S., R. 19 E., northeast corner of sec. 1, in northeast corner of schoolhouse; bronze tablet stamped "1022 IOLA"	1,024.845

Independence Quadrangle.

MONTGOMERY AND WILSON COUNTIES.

The elevations in the following list are based on an aluminum tablet stamped "824 INDEPENDENCE" in the northwest corner of the courthouse at Independence, Kans., the elevation of which is accepted as 827.637 feet above mean sea level. The initial point upon which these levels depend is the bronze tablet established by the Indian Territory (now part of Oklahoma) levels at Coffeyville, Kans., the accepted elevation of which is 4.854 feet higher than that published on page 88, in Bulletin 175.

The leveling was done in 1903 by Fox Wood.

INDEPENDENCE QUADRANGLE.

Coffeyville west along highway 6 miles to Deering, thence north 30 miles, thence east 6 miles, thence south to Coffeyville.[1]

	Feet.
Coffeyville, Ried Building; bronze tablet stamped "731 INDEPENDENCE" (see Indian Territory levels, Bulletin 175)	736.226
Coffeyville, 4 miles west of, on township line, south side of bridge across Onion Creek, in east pier; chiseled cross	740.79
Deering, in southwest corner of store of H. L. Towles; aluminum tablet stamped "763 INDEPENDENCE"	766.954
T. 34 S., R. 16 E., northwest corner of sec. 6, in northwest corner of Meyers's residence; aluminum tablet stamped "882 INDEPENDENCE	884.884
Independence, northwest corner of courthouse; aluminum tablet stamped "824 INDEPENDENCE"	827.637
Sycamore, southeast corner of schoolhouse; aluminum tablet stamped "829 INDEPENDENCE"	831.847
Neodesha, southeast corner of Fourth and Main streets, in north side of brick building (Dr. F. T. Allen's store); aluminum tablet stamped "817 INDEPENDENCE"	820.270
Tps. 29 and 30 S., R. 16 E., on line between secs. 3 and 34, 12 feet from east rail, in east end of concrete railroad culvert; aluminum tablet stamped "842 INDEPENDENCE"	845.770
T. 30 S., R. 17 E., 0.25 mile east of northwest corner of sec. 6, in northeast corner of Mrs. Ann Clegg's house; aluminum tablet stamped "871 INDEPENDENCE"	874.066
T. 31 S., R. 17 E., 0.1 mile east of northwest corner of sec. 6, in northeast corner of schoolhouse (District 80); aluminum tablet stamped "901 INDEPENDENCE"	904.404
T. 32 S., R. 16 E., northeast corner of sec. 12, in wall of schoolhouse; aluminum tablet stamped "843 INDEPENDENCE"	895.524
T. 33 S., R. 16 E., northwest corner of sec. 1, in northwest corner of church; aluminum tablet stamped "758 INDEPENDENCE"	762.141
Liberty, southeast corner of Methodist Church; aluminum tablet stamped "757 INDEPENDENCE"	761.377

Deering west along highway 6 miles to Fawn, thence north about 30 miles to sec. 35, T. 29 S., R. 14 E., thence west 2 miles; return line south from Elk City and Havana to southwest corner T. 24 S., R. 14 E., thence east 6 miles to Fawn.

Tyro, in northeast corner of schoolhouse, aluminum tablet stamped "896 INDEPENDENCE." (Reported destroyed in 1909)	898.627
T. 33 S., R. 15 E., sec. 36, in northwest corner of schoolhouse; aluminum tablet stamped "831 INDEPENDENCE"	833.633
T. 32 S., R. 15 E., northwest corner of sec. 30, in northwest corner of schoolhouse; aluminum tablet stamped "821 INDEPENDENCE"	823.642
T. 31 S., R. 14 E., near sec. 23, southeast corner of schoolhouse; aluminum tablet stamped "918 INDEPENDENCE"	920.626
La Fontaine, in southeast corner of schoolhouse; aluminum tablet stamped "918 INDEPENDENCE"	920.731
T. 29 S., R. 14 E., near sec. 36, in southwest corner of schoolhouse; aluminum tablet stamped "928 INDEPENDENCE"	930.512

[1] The error distributed in this line is excessive.

	Feet.
Buxton, northeast corner of Christian Church; aluminum tablet stamped "979 INDEPENDENCE"	981.384
T. 30 S., R. 14 E., sec. 33, in northwest corner of Henry Cox's residence; aluminum tablet stamped "891 INDEPENDENCE"	893.636
Elk City, in wing of brick schoolhouse; aluminum tablet stamped "833 INDEPENDENCE"	835.887
T. 32 S., R. 14 E., sec. 30, residence of C. Curtis, in west foundation of front porch; aluminum tablet stamped "853 INDEPENDENCE"	855.832
Havana, in schoolhouse; aluminum tablet stamped "762 INDEPENDENCE"	764.178
T. 34 S., R. 14 E., sec. 31, in south side of house of M. M. Freidlin; aluminum tablet stamped "757 INDEPENDENCE"	759.595

Atchison, Kansas City, and Oskaloosa 30′ Quadrangles, including Easton and Leavenworth 15′ Quadrangles.

ATKINS AND LEAVENWORTH COUNTIES.

The elevations are based on bench marks of the Missouri River Commission.

The leveling was done by S. K. Atkinson in 1906 and by G. E. Heebink in 1908–9.

KANSAS CITY 30′ QUADRANGLE.

Standard bench marks of the Missouri River Commission.

	Feet.
P. B. M. 247, Connor, about 2.5 miles above, 1,265 feet below first road crossing below Pope's Siding, 1,315 feet below bridge 79, across small creek, 220 feet above center of small bridge where the Gilman or bottom road turns east away from track, about 0.5 mile east of houses of E. Piper and Mr. Tull; 33 feet west of center of track on line of right of way; copper bolt in bench mark stone	756.023
Top of cap	760.073
P. B. M. 248–77–1, Leavenworth Junction, 2 miles below, opposite foot of Spar Island, 970 feet above milepost 303, 1,610 feet above railroad trestle 81, on second bench from foot of bluff, 120 feet from Missouri Pacific Ry. track; top of copper bolt in bench-mark stone (could not be found in 1909)	799.886
Top of cap	803.964

United States Geological Survey elevations—Point 2.5 miles north of Connor west to Sec. 20, T. 8 S., R. 22 E., and north to Bowling.

Lipps, 310 feet west of post-office box, on south side of road, 6 inches below surface of embankment, marked by large piece of limestone; iron stake marked "803"	802.49
T. 9 S., R. 23 E., at intersection of Dalton and Maltby Roads, on highest part of section corner stone; square marked "882"	882.18
T. 9 S., R. 23 E., southwest corner of sec. 32; corner stone, marked "928"	927.71
Lansing, 2 miles south of by 0.4 mile east of, Leavenworth and Kansas City Road north of Maltby Road, in limestone 3 by 3 feet by 1.5 feet forming abutment of small bridge; aluminum tablet stamped "860"	860.255
T. 9 S., R. 23 E., southwest corner of sec. 31, on stone; chiseled square marked "878"	878.10
Lansing, 0.5 mile south by 1.5 miles west of, intersection of Brighton and Lambourn Roads, quarter corner west side of sec. 26, T. 9 S., R. 22 E.; gas pipe with bronze cap marked "963"	962.385

	Feet.
T. 9 S., R. 22 E., quarter corner on north side of sec 34, near Spring Hill schoolhouse, at T road south, on stone; chiseled square marked "956"..	955. 54
T. 9 S., R. 22 E., southwest corner of sec. 28, at west end of New Lawrence Road, on stone; chiseled square	1,018. 19
T. 9 S., R. 22 E., quarter corner on east side of sec. 29, east end of old Lawrence Road, set 3 feet in ground and projecting 1 foot above ground; iron pipe stamped "1043"	1,042. 787
T. 9 S., R. 22 E., southwest corner of sec. 20, on granite bowlder; chiseled square marked "966"	965. 99
Bowling, 1 mile northeast of, on southeast corner of Atchison, Topeka & Santa Fe Ry. bridge 17; bolt painted white and marked "U. S. 914"...	914. 02

LEAVENWORTH 15′ (KANSAS CITY 30′) QUADRANGLE.

Missouri River Commission bench marks.

P. B. M. 249, Leavenworth Junction, 93 feet above center of station, 100 feet above head block at junction, 18 feet east of center of track, 29.5 feet above lower head block of siding; bolt in bench-mark stone	756. 837
Top of cap	760. 902
P. B. M. 250-78-1, Leavenworth, on shelf of bluff 1⅛ miles below station opposite East Leavenworth, on lower side of small ravine, 200 feet from river and 20 feet west of center of siding leading to coal mine; copper bolt in bench-mark stone	808. 290
Top of cap	812. 356
P. B. M. 251, Leavenworth, north side of the Great Western Stove Co.'s brick building, one block south of Union Station, 3.4 feet west of northeast corner and 5 feet above ground; copper bolt leaded horizontally set in rock, with letters "U. S. ⊙ 415 P. B. M." cut in rock, large enough to be readily seen and deep enough to last many years	782. 300
P. B. M. 252, Leavenworth, in brick building occupied by Rohlfing Bros., grocers, southeast corner of Third and Cherokee Streets, on west end of stone window sill, Cherokee Street side; top of copper bolt leaded vertically and marked "U. S. 415 ⊙ P. B. M."	787. 136
P. B. M. 253, Leavenworth, in retaining wall at northwest corner of Main and Cherokee Streets, 59 feet north of south end of wall, 78 feet south of south end of station; copper bolt leaded horizontally in fourth course of masonry above ground, lettered "U. S. ⊙ P. B. M."	775. 409
P. B. M. 254-79-1, Fort Leavenworth, 30 feet below south face of west abutment of Chicago, Rock Island & Pacific Ry. bridge, 27 feet from center of Missouri Pacific Ry. track, and 8 feet above grade; copper bolt in bench-mark stone	788. 228
Top of cap	792. 314
P. B. M. 255, Fort Leavenworth, in west abutment of Chicago, Rock Island & Pacific Ry. bridge, south side, 3.5 feet back from east face; copper bolt leaded horizontally in fourth course of masonry above ground at southeast corner, lettered "U. S. ⊙ P. B. M."	788. 682
P. B. M. 256, Fort Leavenworth, northeast corner of Government stone ice house on river bank, 7 inches west of east face, and 5.2 feet above ground; copper bolt leaded vertically into building, lettered "U. S. ⊙ P. B. M.".	776. 177
P. B. M. 257, Fort Leavenworth, 0.8 mile above; 1.25 miles above Chicago, Rock Island & Pacific Ry. bridge across Missouri River, 525 feet below wagon-road crossing, 505 feet below center of bridge across small creek at lower edge of wagon road, 150 feet below point of bluff, 28 feet from center of road on side toward bluff; copper bolt set in bench-mark stone.	773. 519
Top of cap	777. 587

	Feet.
P. B. M. 258-80-1, Fort Leavenworth, about 2.25 miles above Chicago, Rock Island & Pacific Ry. bridge, 350 feet above lower head block of Wade siding, on bluff side of track, 2 feet inside right-of-way fence; copper bolt in bench-mark stone	769.361
Top of cap	773.439
P. B. M. 259, Kickapoo, 1.8 miles below, 9 feet above upper end of Missouri Pacific Ry. bridge 95 over Salt Creek, on bluff side, 24 feet from center of track; copper bolt in bench-mark stone	773.966
Top of cap	778.022
P. B. M. 260, Kickapoo, 0.25 mile below, 285 feet below trestle, 1,035 feet above milepost 316, 85 feet above upper end of small bridge, over drain for cut, on bluff side of track, 9.7 feet from center and 2.5 feet above grade; copper bolt leaded horizontally in face of natural ledge, lettered "U. S. ⊙ P. B. M."	794.670
P. B. M. 261-81-1, Kickapoo, on upper side of small ravine, 30 feet from vertical bank of small stream, bluff side of track, 80 feet from center; George Sharp's house bears S. 88° W. (Mag.) 130 feet distant; copper bolt in bench-mark stone	801.567
Top of cap	805.630
P. B. M. 262, Oak Mills, 0.9 mile below, 70 feet below center of railroad bridge over small creek coming out of valley, on bluff side of track, 3 feet east of wire fence directly opposite south point of bluff; copper bolt in bench-mark stone	774.637
Top of cap	778.677
P. B. M. 263, Oak Mills, in northwest side of stone building facing northeast, 65 feet southeast of John Davitz's store, 6 feet above ground and 8 inches from front face of building; copper bolt leaded horizontally, lettered "U. S. ⊙ P. B. M."	790.370
P. B. M. 264-82-1, Oak Mills, in John Davitz's front yard, 19 feet below his store and 2 feet inside tight board fence; copper bolt in bench-mark stone	781.084
Top of cap	785.150
P. B. M. 265, Oak Mills, 2.3 miles, 0.9 mile above Little Walnut Creek, 180 feet below railroad bridge 99, 16 feet toward the river from wagon road running parallel to river, near forks in road, on bluff side of track, 65 feet from center; copper bolt in bench-mark stone	785.551
Top of cap	789.589
P. B. M. 266-83-1, About 5.5 miles below Atchison, 30 feet below lower end of iron bridge across Walnut Creek, on bluff side of track, 68 feet from center and 45 feet north of T. B. M. 541; copper bolt in bench-mark stone	784.806
Top of cap	788.832

Leavenworth west to Hund, thence south 1 mile (United States Geological Survey bench marks).

Hund, 40 feet south of Union Pacific R. R. tracks, 20 feet west of wagon road; iron post stamped "834"	833.341
Hund, 1 mile south of, on stone abutment of steel bridge 130; chiseled square marked "846"	830.12

OSKALOOSA 30′ QUADRANGLE.

Springdale south to Ackerland, thence east along railroad to Boling.

Springdale, 1.5 miles south of, at crossroads near mail box 60, in north root of forked oak tree; nail	948.209
Ackerland, 1 mile north of, northeast corner of sec. 36, T. 9 S., R. 20 E.; section stone marked "1006"	1,006

	Feet.
Ackerland, 300 feet east of station, intersection of railroad with main north and south pike; point on track, marked "1041"	1,040.08
Ackerland, 1 mile east of, 2 miles west of Jarbalo, on southwest corner of railroad bridge 32, bolt painted white and marked "U. S. 971"	970.89
Milepost 15; top of rail	965.96
Jarbalo, 1 mile west of, railroad crossing; joint on south rail, marked "919".	918.55
Jarbalo, 120 feet east of station, 30 feet south of tracks; iron post stamped "871"	871.223
Jarbalo, 1 mile east of, southwest corner of bridge 29; bolt painted white and marked "857"	856.75
Jarbalo, 2 miles east of, in southeast corner of bridge 26; bolt painted white and marked "866"	865.05
Milepost 11; top of vertical rail	874.19
Bowling, in front of sign; top of rail	916.6
Bowling, 200 feet northeast of station, 3 feet south of main track; large iron cylinder set in ground, marked "U. S. 914"	913.37

Corner of secs. 14, 15, 22, and 23, T. 9 S., R. 20 E., south 1.5 miles, thence west 2.5 miles, thence north to sec. 17.

T. 9 S., R. 20 E., quarter corner between secs. 26 and 27, 5.2 feet from ground, near crotch in 20-inch elm tree at T road; 40-penny nail	998.20
T. 9 S., R. 20 E., quarter corner between secs. 27 and 28; iron post	1,049.008
T. 9 S., R. 20 E., quarter corner between secs. 28 and 29, cross corner, in telephone post; two 40-penny nails	1,065.84
T. 9 S., R. 20 E., center of sec. 29, 10 feet from corner fence post, 18 inches above ground, in brace of corner fence post; 40-penny nail	1,104.32

EASTON 15′ (OSKALOOSA 30′) QUADRANGLE.

Point near Bowling north to point near Hund.

Bowling, near, in old ravine near where road crosses creek bed of west fork of Little Stranger Creek; stone marked "U. S. 913"	912.78
Lansing, 5 miles west of, at intersection of roads, northeast corner of sec. 24, T. 9 S., R. 21 E., 50 feet west of bridge 92, south side of road; iron pipe with brass cap stamped "972"	971.451
T. 9 S., R. 22 E., northwest corner of sec. 18, at crossroads near High Prairie schoolhouse, on limestone; chiseled square marked "1075"	1,074.80
T. 9 S., R. 22 E., quarter corner on west side of sec. 7, south side of Compton Road; marked "1066"	1,066.24
T. 8 S., R. 22 E., southwest corner of sec. 31, at intersection of roads, in Possum Hollow; in stone; aluminum tablet marked "924"	925.310

Hund west along Union Pacific Railroad to point 7 miles west of Easton.

T. 8 S., R. 21 E., near quarter corner on east side of sec. 13, on Union Pacific R. R., at intersection of road with railroad crossing; pole marked "U. S. 873"	872.6
Pleasant Ridge, southwest corner of box-car station, in platform; 40-penny nail	1,050.37
Easton, main crossing; top of rail	903.7
Easton, intersection of Riley Street and main north and south road; on southwest corner of H. Boyle's place; iron post stamped "904"	903.443
Easton, in stone step of Methodist Episcopal Church, 0.3 mile west of intersection of Riley Street with main north and south road, at end of Riley Street; aluminum tablet stamped "909"	908.590
T. 8 S., R. 20 E., quarter corner between secs. 18 and 19; iron post	1,171.265

Pleasant Ridge northeast to Oak Mills.

	Feet.
T. 8 S., R. 21 E., center of sec. 3, intersection of roads, in center of road, in limestone section corner at northeast corner of Squire's place; aluminum tablet stamped "1098." (Bench mark has been disturbed.)	1,098.212
T. 7 S., R. 21 E., center of sec. 34, west side of road on piece of limestone; chiseled square; marked "1086"	1,085.86
T. 7 S., R. 21 E., quarter corner between secs. 23 and 24, northwest corner of Joe Adams's place, southeast corner of intersecting roads; iron post stamped "1008"	1,007.843
Oak Mills, in John Davitz's front yard, 19 feet below his store and 2 feet inside of his tight board fence; iron pipe set 4 feet in ground, cap terminating in round knob taken as bench mark, stamped "Missouri River Commission P. B. M. No. 264 -82-1"	785.150

Oak Mills west and south to Easton.

Oak Mills, 1.5 miles south of and 1.5 miles west of, on half section road at corner of Henry Paseway's place; large granite bowlder marked "U. S. 1028"	1,027.88
Oak Mills, 1.5 miles south of and 3.5 miles west of, at crossroads, quarter corner on east side of sec. 21, R. 21 E., T. 7 S.; iron post stamped "1054".	1,054.039
T. 7 S., R. 21 E., center of sec. 21, at intersection of roads; stone marked "U. S. 1054"	1,054.26
Potter, 2 miles east of, southeast corner of NE. ¼ sec. 19, T. 7 S., R. 21 E., at crossroads; iron pipe stamped "1008"	1,007.607
Easton, 3.5 miles north of, on west side of main pike, in front of Henry Seute's farm; center of large stone marked "997"	997.05
Easton, 3 miles north of, 0.25 mile east of Melwood, at fork in road, near Max Blecher's mail box; iron post stamped "924"	924.217
Easton, 1.5 miles north of, on bridge 158, northeast corner of, on railing; nail with white square, marked "906"	906.34

Easton south to point 1.5 miles south of Springdale.

Easton, 1 mile south of, southeast corner of bridge 179; bolt painted "U. S. 887"	887.40
Springdale, 4 miles north of, southwest corner of front door step of W. A. Hastey's place; marked "U. S. 923"	923.59
Easton, 3.3 miles south of, at base of telegraph pole; highest point on rock painted "940"	940
Easton, 4.6 miles south of, west of road, northwest of white house on east side of road, in root of tree; 40-penny nail	881.15
Springdale, on main east and west road, in front of John McQuillan's residence on north side of road; iron pipe stamped "1048"	1,046.173
Springdale, 1.5 miles south of, forks in road, northeast corner of Ezra Martz's place; stone marked "U. S. 979"	978

Springdale west 5.5 miles, thence north to point 1 mile north of Cummings, thence east and north to point near Parnell.

Springdale, 1 mile west of, in brace of corner fence post; 40-penny nail.	1,056.45
T. 9 S., R. 20 E., corner of secs. 14, 15, 22, and 23, in corner fence post; 40-penny nail	1,042.24
Edmunds Church corner, 50 feet from corner fence post, in root of elm tree 7 inches in diameter; 40-penny nail	1,063.63
T. 9 S., R. 20 E., 35 feet north of and 15 feet east of quarter corner between secs. 18 and 19, on east side of north-south road; iron post stamped "Prim. Trav. Sta. No. 7-1906"	1,092.209

	Feet.
T. 9 S., R. 20 E., quarter corner between secs. 7 and 18	1,076.35
T. 9 S., R. 20 E., quarter corner between secs. 6 and 7, at crossroad, in corner fence post; 40-penny nail	1,011.94
Tps. 8 and 9 S., R. 20 E., quarter corner between secs. 6 and 31; iron post	1,090.055
Tps. 8 and 9 S., Rs. 19 and 20 E., corner of secs. 1, 6, 31, and 36; at crossroad; top of corner stone	1,100.16
T. 8 S., Rs. 19 and 20 E., corner of secs. 25, 30, 31, and 36; top of corner stone	1,123.36
T. 8 S., Rs. 19 and 20 E., quarter corner between secs. 30 and 25, in telephone post; three 40-penny nails	1,092.20
T. 8 S., R. 20 E., center of sec. 30, at crossroad, in telephone post; three 40-penny nails	1,124.30
T. 8 S., R. 20 E., quarter corner between secs. 18 and 19; iron post	1,171.265
T. 8 S., R. 20 E., quarter corner between secs. 6 and 7, at crossroad, in telephone post; two 40-penny nails	1,125.17
Corpus Christi Church, 0.5 mile west of, at crossroad, in corner fence post; three 40-penny nails	1,120.46
Corpus Christi Church, 1 mile west of Tps. 7 and 8 S., Rs. 19 and 20 E.; iron post stamped "Prim. Trav. Sta. No. 9–1906"	1,092.178
T. 7 S., Rs. 19 and 20 E., quarter corner between secs. 30 and 25, at crossroad, in corner fence post; four 40-penny nails	1,128.98
T. 7 S., Rs. 19 and 20 E., corner of secs. 19, 30, 24 and 25, T corner, in root of 8-inch locust tree; 40-penny nail	1,045.96
T. 7 S., Rs. 19 and 20 E., corner of secs. 13, 18, 19, and 24, on southeast corner of east abutment of iron bridge; painted square	966.80
T. 7 S., R. 19 E., quarter corner between secs. 13 and 24, on east side of north and south road, 10 feet from corner fence post; iron post	991.808
T. 7 S., R. 19 E., quarter corner between secs. 12 and 13, in west root of tree; 40-penny nail	1,087.00
T. 7 S., R. 19 E., center of sec. 12, in corner fence post at northwest corner of crossing; two 40-penny nails	1,030.15
T. 7 S., R. 19 E., quarter corner between secs. 1 and 12, T corner, in telephone post near E. W. Kaufman's general store; three 40-penny nails	984.09
Cummings, 1 mile north of Tps. 6 and 7 S., R. 19 E., quarter corner between secs. 1 and 36, T corner, in yard of house at end of T road; iron post	1,063.746
Tps. 6 and 7 S., Rs. 19 and 20 E., township corner; top of section corner stone	985.17
Hawthorne, opposite station, in telephone pole east of tracks; three 40-penny nails	960.82
Bridge 13, northwest abutment of; painted square	969.08
Bridge 12, southwest abutment of; painted square	1,010.62

Sec. 19, T. 7 S., R. 21 E., west to Potter, thence northwest along Atchison, Topeka & Santa Fe Ry. to Hawthorne.

Potter, 1.8 miles east of, south of road; cross on stone	982.88
Potter, in front of station; top of rail	934.3
Mount Pleasant, northwest corner of station; top of rail	946.1
Mount Pleasant, 2 miles northwest of, at railroad culvert 5; top of south rail	963.7
Hawthorne, in front of station, in telephone pole east of track; three 40-penny nails	960.82
Hawthorne, northwest abutment of bridge 13; painted square	969.08

ATCHISON 30' QUADRANGLE.

Parnell northeast along Atchison, Topeka & Santa Fe Ry. to Atchison, thence south along Missouri Pacific Ry. to P. B. M. 267, Missouri River Commission.

	Feet.
Parnell, 35 feet west of general store and post office; iron post	1,054.477
Bridge 10, Atchison, Topeka & Santa Fe Ry., northwest corner of north abutment; painted square	954.78
Bridge 9, northwest corner of north abutment; painted square	929.76
Bridge 8, north side of east abutment; painted square	907.42
Parnell, 3 miles north of, near railroad crossing; iron post	907.729
Bridge 7, north end of east abutment; painted square	871.80
Bridge 6, north end of east abutment; painted square	860.60
Bridge 5, Atchison, Topeka & Santa Fe Ry., west abutment; painted square	849.96
Bridge 106, Missouri Pacific Ry., west end of north abutment; painted square	790.640
Atchison, 3 miles below union station, 130 feet below milepost 327, on side of track near bluff, 59 feet from center of track, 10 feet above grade, 16 feet toward river from wagon road, and 8 feet southeast of 10-inch crab-apple tree; copper bolt in bench-mark stone. (Top of copper bolt set in regulation bench-mark stone 18 by 18 by 4 inches thick, 3.5 feet underground, over and concentric with which is set an iron pipe 4 feet long provided with a flange at the bottom 10 inches in outer diameter and cap at top terminating in a rounded knob, which is also taken as a permanent bench mark. The top surface of flat stone is marked "B. M."; copper bolt	796.356
Top of cap	800.418

Garden, Lakin, Syracuse, and Tribune Quadrangles.

FINNEY, GRANT, HAMILTON, KEARNEY, AND STANTON COUNTIES.

The elevations in the following list are based on the bronze tablet marked "2832," in the southwest corner of the courthouse at Garden, the accepted elevation of which is 2,832.034 feet above mean sea level. The initial height from which this bench mark is established is the top of the rail on the main track of the Atchison, Topeka & Santa Fe Ry., in front of the telegraph office at Garden, using the railroad company's elevation, 2,829 feet.

The leveling in this area was done by M. C. McFarlane in 1897, J. C. Barber in 1896, and F. C. French in 1898.

GARDEN QUADRANGLE.

Garden along Atchison, Topeka & Santa Fe Ry. to Sec. 7, T. 24 S., R. 33 W.

	Feet.
Garden, Atchison, Topeka & Santa Fe Ry., in front of telegraph office; top of rail	2,829
Garden, southwest corner of courthouse; copper plate stamped "G. C. 2832"	2,832.034
Garden, First National Bank, southwest side of main entrance; bronze tablet stamped "G. C. 2830"	2,830.185
T. 24 S, R. 33 W., on north and south line through center of sec. 15, 48 feet south of Atchison, Topeka & Santa Fe Ry. track, between Garden and Sherlock; iron post stamped "G. C. 2853"	2,853.022
T. 24 S., R. 33 W., 450 feet north and 70 feet west of east quarter corner of sec. 7, south side of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 2870"	2,869.964

LAKIN QUADRANGLE.

Bench marks established near public land corners.

	Feet.
T. 29 S., R. 37 W., southwest corner of sec. 18; iron post stamped "G. C. 3098"	3,098.008
T. 29 S., R. 37 W., southeast corner of sec. 13; iron post stamped "G. C. 2978"	2,977.752
T. 29 S., R. 36 W., southeast corner of sec. 16; iron post stamped "G. C. 3016"	3,015.693
T. 29 S., R. 36 W., southeast corner of sec. 13; iron post stamped "G. C. 3023"	3,022.951
T. 29 S., R. 35 W., southeast corner of sec. 16; iron post stamped "G. C. 3010"	3,010.008
T. 29 S., R. 35 W., southeast corner of sec. 13; iron post stamped "G. C. 3020"	3,020.262
T. 28 S., R. 38 W., southeast corner of sec. 36; iron post stamped "G. C. 3049"	3,049.049
T. 28 S., R. 38 W., southeast corner of sec. 33; iron post stamped "G. C. 3106"	3,106.486
T. 28 S., R. 37 W., southeast corner of sec. 9; iron post stamped "G. C. 3053"	3,053.185
T. 28 S., R. 37 W., southeast corner of sec. 29; iron post stamped "G. C. 3050"	3,049.598
T. 28 S., R. 36 W., southwest corner of sec. 34; iron post stamped "G. C. 3048"	3,047.667
T. 28 S., R. 36 W., southwest corner of sec. 31; iron post stamped "G. C. 3059"	3,059.232
T. 28 S., R. 35 W., southwest corner of sec. 34; iron post stamped "G. C. 3020"	3,020.412
T. 28 S., R. 35 W., southwest corner of sec. 31; iron post stamped "G. C. 3048"	3,047.640
T. 28 S., R. 34 W., southwest corner of sec. 34; iron post stamped "G. C. 2999"	2,999.367
T. 28 S., R. 34 W., southwest corner of sec. 31; iron post stamped "G. C. 3007"	3,006.790
T. 27 S., R. 38 W., southeast corner of sec. 33; iron post stamped "G. C. 3092"	3,091.805
T. 27 S., R. 38 W., southeast corner of sec. 36; iron post stamped "G. C. 3078"	3,078.245
T. 27 S., R. 37 W., southeast corner of sec. 16; iron post stamped "G. C. 3055"	3,054.867
T. 27 S., R. 37 W., southeast corner of sec. 33; iron post stamped "G. C. 3060"	3,060.400
T. 27 S., R. 36 W., southwest corner of sec. 34; iron post stamped "G. C. 3094"	3,093.825
T. 27 S., R. 36 W., southwest corner of sec. 31; iron post stamped "G. C. 3016"	3,016.146
T. 27 S., R. 35 W., southwest corner of sec. 34; iron post stamped "G. C. 3076"	3,076.041
T. 27 S., R. 35 W., southwest corner of sec. 31; iron post stamped "G. C. 3119"	3,118.557
T. 27 S., R. 34 W., southwest corner of sec. 34; iron post stamped "G. C. 3074"	3,073.887
T. 27 S., R. 34 W., southwest corner of sec. 31; iron post stamped "G. C. 3054"	3,054.285

	Feet.
T. 26 S., R. 38 W., southeast corner of sec. 36; iron post stamped "G. C. 3089"	3,089.083
T. 26 S., R. 38 W., southeast corner of sec. 33; iron post stamped "G. C. 3177"	3,177.267
T. 26 S., R. 37 W., south side of sec. 16, 120 feet west of Hartland-Ulysses wagon road; iron post stamped "G. C. 3048"	3,048.417
T. 26 S., R. 37 W., southeast corner of sec. 33; iron post stamped "G. C. 3069"	3,068.838
T. 26 S., R. 36 W., southwest corner of sec. 33; iron post stamped "G. C. 3084"	3,083.716
T. 26 S., R. 36 W., southwest corner of sec. 31; iron post stamped "G. C. 3080"	3,079.725
T. 26 S., R. 35 W., southwest corner of sec. 34; iron post stamped "G. C. 3026"	3,026.328
T. 26 S., R. 35 W., southwest corner of sec. 31; iron post stamped "G. C. 3098"	3,097.876
T. 26 S., R. 34 W., southwest corner of sec. 34; iron post stamped "G. C. 2990"	2,990.128
T. 26 S., R. 34 W., 620 feet east of southwest corner of sec. 31; iron post stamped "G. C. 3010"	3,009.998
T. 25 S., R. 34 W., northwest corner of sec. 6; iron post stamped "G. C. 2967"	2,966.901
T. 25 S., R. 35 W., northwest corner of sec. 3; iron post stamped "G. C. 2984"	2,984.394
T. 25 S., R. 35 W., northwest corner of sec. 6; iron post stamped "G. C. 2975"	2,975.357
T. 25 S., R. 37 W., near south side of township, west side of Hartland-Ulysses wagon road; iron post stamped "G. C. 3039"	3,038.718
T. 25 S., R. 36 W., 40 feet southeast from northwest corner of sec. 2; iron post stamped "G. C. 2990"	2,989.798
T. 25 S., R. 38 W., 650 feet west of east side of sec. 3, south of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 3112"	3,112.044
T. 25 S., R. 37 W., line between secs. 7 and 8, north of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 3063"	3,063.102
T. 25 S., R. 37 W., 600 feet north of southeast corner of sec. 10, north of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 3040"	3,039.891
T. 25 S., R. 36 W., 1,050 feet south of northwest corner; iron post stamped "G. C. 3013"	3,012.963
T. 24 S., R. 36 W., 60 feet east of line between secs. 26 and 27; south side of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 2991"	2,990.914
T. 24 S., R. 35 W., 6 feet west of line between secs. 17 and 18, south of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 2969"	2,968.966
Deerfield, 2,200 feet west of station; 6 feet west of line between secs. 10 and 11, T. 24 S., R. 35 W., south side of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 2940"	2,940.104
T. 24 S., R. 34 W., 1,417 feet south of east quarter corner of sec. 6, south of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 2908"	2,908.059
T. 24 S., R. 34 W., 1,100 feet south and slightly west of east quarter corner of sec. 3, south of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 2892"	2,892.095
T. 24 S., R. 36 W., southeast corner of sec. 3; iron post stamped "G. C. 3125"	3,125.493
T. 24 S., R. 37 W., northeast corner of sec. 21; iron post stamped "G. C. 3244"	3,243.950

	Feet.
T. 24 S., R. 38 W., southeast corner of sec. 13; iron post stamped "G. C. 3267"	3,267.141
Hartland, 0.5 mile west of; iron post stamped "G. C. 3040"	3,039.891
T. 24 S., R. 37 W., near quarter corner on west side of sec. 34, triangulation station; iron post stamped "G. C. 3249"	3,248.939

SYRACUSE QUADRANGLE.

Bench marks established near public-land corners.

T. 29 S., R. 38 W., southwest corner of sec. 18; iron post stamped "G. C. 3139"	3,138.822
T. 28 S., R. 41 W., quarter corner east side of sec. 33; iron post stamped "G. C. 3375"	3,375.345
T. 28 S., R. 42 W., southeast corner of sec. 36; iron post stamped "G. C. 3408"	3,407.600
T. 28 S., R. 42 W., southeast corner of sec. 33; iron post stamped "G. C. 3446"	3,446.344
T. 28 S., R. 41 W., southeast corner of sec. 36; iron post stamped "G. C. 3329"	3,328.581
T. 28 S., R. 41 W., southwest corner of sec. 13; east side Syracuse-Johnson wagon road; iron post stamped "G. C. 3341"	3,341.298
T. 28 S., R. 40 W., southeast corner of sec. 36; iron post stamped "G. C. 3222"	3,222.096
T. 28 S., R. 40 W., southeast corner of sec. 33; iron post stamped "G. C. 3276"	3,275.937
T. 28 S., R. 39 W., southeast corner of sec. 36; iron post stamped "G. C. 3117"	3,117.370
T. 28 S., R. 39 W., southeast corner of sec. 33; iron post stamped "G. C. 3187"	3,186.517
T. 27 S., R. 42 W., southeast corner of sec. 33; iron post stamped "G. C. 3477"	3,476.965
T. 27 S., R. 42 W., southeast corner of sec. 36; iron post stamped "G. C. 3396"	3,396.443
T. 27 S., R. 41 W., southeast corner of sec. 33; iron post stamped "G. C. 3351"	3,351.435
T. 27 S., R. 41 W., southwest corner of sec. 36; iron post stamped "G. C. 3304"	3,304.393
T. 27 S., R. 40 W., southeast corner of sec. 33; iron post stamped G. C. 3264"	3,264.377
T. 27 S., R. 40 W., southeast corner of sec. 36; iron post stamped "G. C. 3193"	3,192.658
T. 27 S., R. 39 W., southeast corner of sec. 33; iron post stamped "G. C. 3164"	3,164.082
T. 27 S., R. 39 W., southeast corner of sec. 36; iron post stamped "G. C. 3126"	3,126.269
T. 27 S., R. 41 W., southwest corner of sec. 36, east of Syracuse-Johnson wagon road; iron post stamped "G. C. 3304"	3,304.343
T. 27 S., R. 41 W., southwest corner of sec. 13, east of Syracuse-Johnson wagon road; iron post stamped "G. C. 3284"	3,283.775
T. 26 S., R. 39 W., northwest corner of sec. 6; iron post stamped "G. C. 3409"	3,408.531
T. 26 S., R. 39 W., quarter corner of east side of sec. 14; iron post stamped "G. C. 3322"	3,321.580
T. 26 S., R. 40 W., northeast corner of sec. 6; iron post stamped "G. C. 3470"	3,470.236

	Feet.
T. 26 S., R. 40 W., northeast corner of sec. 3; iron post stamped "G. C. 3437"	3,436.912
T. 26 S., R. 42 W., northeast corner of sec. 5; iron post stamped "G. C. 3434"	3,433.710
T. 26 S., R. 42 W., northeast corner of sec. 2; iron post stamped "G. C. 3430"	3,430.353
T. 26 S., R. 41 W., southwest corner of sec. 36, east of Syracuse-Johnson wagon road; iron post stamped "G. C. 3265"	3,265.164
T. 26 S., R. 41 W., 30 feet west and 30 feet south of northeast corner of sec. 23, on wagon road from Syracuse to Johnson; iron post stamped "G. C. 3362"	3,362.130
T. 25 S., R. 38 W., southwest corner of sec. 31; iron post stamped "G. C. 3254"	3,254.289
T. 25 S., R. 39 W., northeast corner of sec. 4; iron post stamped "G. C. 3176"	3,175.511
T. 25 S., R. 39 W., southeast corner of sec. 3; iron post stamped "G. C. 3381"	3,381.016
T. 25 S., R. 41 W., southeast corner of sec. 33; iron post stamped "G. C. 3430"	3,430.353
T. 25 S., R. 42 W., northeast corner of sec. 4; iron post stamped "G. C. 3489"	3,489.429
T. 25 S., R. 42 W., southeast corner of sec. 16; iron post stamped "G. C. 3522"	3,522.101
T. 25 S., R. 41 W., 30 feet west of Johnson wagon road; iron post stamped "G. C. 3392"	3,392.481
Syracuse, about 8 miles south of, triangulation station on west side of Johnson road; iron post stamped "G. C. 3508"	3,507.505
T. 25 S., R. 40 W., southwest corner of sec. 31; iron post stamped "G. C. 3489"	3,488.934
T. 25 S., R. 38 W., 70 feet southeast of northwest corner of sec. 6; iron post stamped "G. C. 3147"	3,146.576
T. 24 S., R. 41 W., near center of sec. 2; iron post stamped "G. C. 3247"	3,246.611
T. 24 S., R. 42 W., southeast corner of sec. 36; iron post stamped "G. C. 3435"	3,435.419
T. 24 S., R. 42 W., east side of sec. 1, at fence corner 50 feet south of Arkansas River; iron post stamped "G. C. 3267"	3,266.986
T. 24 S., R. 41 W., 10 feet east of fence between secs. 3 and 4, 47 feet south of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 3254"	3,254.315
T. 24 S., R. 40 W., 1,765 feet south and 30 feet east from northwest corner of sec. 7, 47.5 feet south of Atchison, Topeka & Santa Fe Ry. tracks; iron post stamped "G. C. 3230"	3,230.315
T. 24 S., R. 40 W., 15 feet west of line between secs. 15 and 16, 46.5 feet south of Atchison, Topeka & Santa Fe Ry. tracks; iron post stamped "G. C. 3198"	3,198.401
T. 24 S., R. 39 W., 15 feet east and 10 feet south of northwest corner of sec. 19, 46 feet south of Atchison, Topeka & Santa Fe Ry. tracks; iron post stamped "G. C. 3175"	3,175.261
T. 24 S., R. 39 W., 12 feet west of line between secs. 22 and 21, south of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 3152"	3,152.234
T. 24 S., R. 38 W., 150 feet east of west side of sec. 30, north of Atchison, Topeka & Santa Fe Ry. tracks; iron post stamped "G. C. 3123"	3,122.988

TRIBUNE QUADRANGLE.

Bench marks established near public-land corners.

	Feet.
T. 23 S., R. 42 W., 12 feet east of fence between secs. 31 and 36, 47 feet south of Atchison, Topeka & Santa Fe Ry. tracks; iron post stamped "G. C. 3278"	3,277.882
T. 23 S., R. 42 W., 1,848 feet south of northwest corner of sec. 27, 48 feet south of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 3303"	3,302.939
T. 23 S., R. 42 W., 12 feet east of west side of sec. 19, 48 feet south of Atchison, Topeka & Santa Fe Ry. tracks, 1.8 miles east of Coolidge; iron post stamped "G. C. 3337"	3,337.015
T. 23 S., R. 43 W., 423 feet south of northwest corner of sec. 22, 48 feet south of Atchison, Topeka & Santa Fe Ry. track; iron post stamped "G. C. 3353"	3,352.684

NEBRASKA.

PRIMARY LEVELING.

Elk Point Quadrangle.

DIXON COUNTY.

The elevations in the following list were determined by primary leveling extended from bench marks of the Missouri River Commission. A correction of +0.755 foot has been added to the values published in Part 3 of the Report of the Chief of Engineers, United States Army, for 1894, at and west of Elk Point, a junction point with a precise level line of the Coast and Geodetic Survey, which crosses this quadrangle along the Chicago, Milwaukee, & St. Paul Ry.

The leveling was done in 1898 by D. C. Wray.

Elevations in South Dakota and Iowa in this quadrangle are given in Bulletins 472 and 460 respectively.

ELK POINT QUADRANGLE.

Ponca Ferry south to corner of Tps. 29 and 30 N., Rs. 6 and 7 E., thence west to line of Rs. 5 and 4, thence north to line of Tps. 30 and 31 N., thence east to line of Rs. 5 and 6.

	Feet.
P. B. M. 355-1, Missouri River Commission (redetermined by Coast and Geodetic Survey), west bank, at foot of bluffs, about 0.5 mile below Ponca Landing, in farm yard of John Austin, about 300 feet southwest from his dwelling house and 250 feet south of road between Ponca and Ponca Landing; copper bolt in bench mark stone set 4 feet under ground, covered by a 3-inch iron pipe marked "U. S. B. M"	1,119.332
T. 30 N., R. 6 E., one-fourth mile west from southwest corner of sec. 36; iron post stamped "YNKTN 1348"	1,348.685
T. 29 N., R. 6 E., northwest corner of sec. 6, in schoolhouse yard; iron post stamped "YNKTN 1211"	1,212.244
T. 29 N., R. 5 E., northwest corner of sec. 6; iron post stamped "YNKTN 1465"	1,465.987
T. 30 N., R. 5 E., northwest corner of sec. 6; iron post stamped "YNKTN 1466"	1,467.181

Ponca northwest along highway to T. 32 N., R. 4 E.

	Feet.
T. 31 N., R. 5 E., southwest corner of sec. 36; iron post stamped "YNKTN 1296"	1,297.211
T. 31 N., R. 5 E., northwest corner of sec. 6; iron post stamped "YNKTN 1166"	1,167.105

Nehawka, Omaha, and Weeping Water quadrangles.

CASS, JOHNSON, LANCASTER, OTOE, AND SARPY COUNTIES.

The elevations in the following list are based on bench marks of the Missouri River Commission in the vicinity of Omaha, Nebr., and on stone lines at Plattsmouth and Nebraska City run from the main precise level line bench marks 336 and 327 on the Iowa side of the Missouri River.

The leveling in the Nehawka and Omaha quadrangles and in the north half of the Weeping Water quadrangle was done in 1902 by M. A. Steele; that in the south half of the Weeping Water quadrangle was done in 1902 by John Wilson.

OMAHA QUADRANGLE.

At Plattsmouth.

	Feet.
Plattsmouth, at railroad bridge across the Missouri River, 10 feet south and on line with first trestle bent west of west pier; copper bolt in bench mark stone (Missouri River Commission bench mark "336 B")	954.059
Plattsmouth, in courthouse yard, 6 inches east of masonry base of cannon; iron post stamped "990 OMAHA"	989.245
Plattsmouth, in front of station; top of rail	1,063.1-

NEHAWKA QUADRANGLE.

Mynard south via Missouri Pacific Railway to Murray.

Mynard, in front of station; top of rail	1,086.8
Murray, in front of station; top of rail	1,146.0
Murray, in northwest corner of schoolhouse yard, 23 feet north of northwest corner of building; iron post stamped "1189 OMAHA"	1,188.216

WEEPING WATER QUADRANGLE.

Southwest corner of Sec. 15, T. 11 N., R. 12 E., along highways to southwest corner of Sec. 2, T. 10 N., R. 12 E.

T. 11 N., R. 12 E., southwest corner of sec. 15, 36.5 feet north and 21 feet east of center of crossroads; iron post stamped "1251 OMAHA"	1,250.910
T. 11 N., R. 11 E., southeast corner of sec. 16, 10 feet north and 2 feet east of 15-inch cottonwood tree; iron post stamped "1302 OMAHA"	1,302.027
T. 11 N., R. 10 E., southeast corner of sec. 16, 33 feet west and 36 feet north of center of crossroads; iron post stamped "1282 OMAHA"	1,281.278
T. 11 N., R. 9 E., southwest corner of sec. 15, 32 feet east and 37.5 feet north of center of crossroads; iron post stamped "1256 OMAHA"	1,256.022
T. 11 N., R. 8 E., 0.25 mile south of northwest corner of sec. 24, 2 feet east and 2 feet south of corner fence post at south corner of intersection of north-south and east-west roads; iron post stamped "1143 OMAHA"	1,142.710
T. 12 N., R. 12 E., northwest corner of sec. 34, 40.5 feet north and 44 feet west of northwest corner of schoolhouse; iron post stamped "1218 OMAHA"	1,217.352

	Feet.
T. 10 N., R. 12 E., southwest corner sec. 2, in southeast corner of schoolhouse yard, 66 feet south and 57 feet east of southeast corner of building (schoolhouse 38); iron post stamped "1119 OMAHA"	1,118.515

Center of T. 11 N., R. 9 E., south to center of T. 9 N., R. 9 E.

T. 10 N., R. 9 E., northwest corner of sec. 27, 34.5 feet east and 42 feet south of center of crossroads; iron post stamped "1329 OMAHA"	1,328.295

Center of T. 11 N., R. 9 E., north 5 miles, thence east 5 miles, thence south 5 miles.

T. 12 N., R. 9 E., southeast corner of sec. 21, 37.5 feet north and 31.5 feet west of center of crossroads; iron post stamped "1113 OMAHA"	1,112.627
T. 12 N., R. 10 E., northwest corner of sec. 33, 22 feet east and 22 feet south of center of crossroads; iron post stamped "1221 OMAHA"	1,220.530

Southeast corner of Sec. 14, T. 11 N., R. 11 E., south 5 miles, thence west 2 miles, thence south 7 miles to center of T. 9 N., R. 11 E.

Weeping Water, in front of station; top of rail	1,080.0
Weeping Water, 97.5 feet north by 95.5 feet east of northeast corner of High School Building, in school yard; iron post stamped "1084 OMAHA"	1,083.838

Center of T. 10 N., R. 11 E., west 6 miles, thence north to center of T. 11 N., R. 10 E.

Elmwood, 3 feet south by 3 feet east of northwest corner of water tower; iron post stamped "1295 OMAHA"	1,294.573

Dunbar west along Missouri Pacific Ry. to point near center of T. 8 N., R. 12 E., thence north to center of T. 9 N., R. 12 E., and return.

Dunbar, in front of Missouri Pacific Railway station; top of rail	1,049.98
Dunbar, in front of Chicago, Burlington & Quincy R. R. station; top of rail	1,049.35
T. 8 N., R. 12 E., corner of secs. 9, 10, 15, and 16, 2 feet east of southeast corner of crossroads; iron post stamped "1101 OMAHA"	1,100.435
T. 9 N., R. 12 E., southeast corner of sec. 16, in southwest corner of schoolhouse yard; iron post stamped "1215 OMAHA"	1,214.798

Dunbar west to Syracuse, thence north to center of T. 9 N., R. 9 E., west through T. 9 N., south in R. 9 E., and east through T. 8 N., to Syracuse with checked spur east into R. 8 E.

Syracuse, 1 mile north of, at northwest corner of sec. 15, T. 8 N., R. 11 E., 2 feet south and 8 feet east of southeast corner of road crossing; iron post stamped "1132 OMAHA"	1,131.690
T. 9 N., R. 11 E., northwest corner of sec. 27, in northwest corner of schoolhouse yard; iron post stamped "1262 OMAHA"	1,261.566
T. 9 N., R. 10 E., southeast corner of sec. 16, 25 feet north and 1 foot east of northwest corner of road crossing; iron post stamped "1259 OMAHA"	1,259.736
T. 9 N., R. 9 E., northeast corner sec. 21, in southeast corner of schoolhouse yard; iron post stamped "1310 OMAHA"	1,309.446
T. 9 N., R. 8 E., southwest corner sec. 24, east of schoolhouse; iron post stamped "1313 OMAHA"	1,312.057
T. 8 N., R. 9 E., northwest corner sec. 14, 20 feet east and 1 foot north of southeast corner of road crossing; iron post stamped "1150 OMAHA"	1,151.741
Unadilla, 2 miles south of, at southeast corner of sec. 15, T. 8 N., R. 10 E., 12 feet west and 1 foot south of road crossing; iron post stamped "1231 OMAHA"	1,230.697

Palmyra south through R. 9 E., thence east in T. 7 N. and north in R. 12 E. to point near Dunbar, with checked spur east into R. 8 E. and south into T. 6 N.

	Feet.
T. 8 N., R. 9 E., northwest corner of sec. 35, 35 feet due east of corner stone; iron post stamped "1316 OMAHA"	1,315.915
Douglas, 0.5 mile south of, at southwest corner of sec. 11, T. 7 N., R. 9 E., 6 feet south and 3 feet west of southeast corner of road crossing; iron post stamped "1265 OMAHA"	1,264.658
T. 7 N., R. 10 E., southeast corner of sec. 16, in southeast corner of schoolhouse (district 107) yard; iron post stamped "1289 OMAHA"	1,288.890
T. 7 N., R. 11 E., southeast corner of sec. 15, 8 feet north and 1 foot east of northwest corner of crossroads; iron post stamped "1064 OMAHA"	1,063.368
T. 7 N., R. 12 E., northwest corner of sec. 23, 20 feet east and 2 feet north of southeast corner of crossing of roads; iron post stamped "982 OMAHA".	981.326
T. 7 N., R. 8 E., northeast corner of sec. 14, near schoolhouse northeast of road crossing, in southeast corner of schoolhouse yard; iron post stamped "1424 OMAHA"	1,423.944
T. 6 N., R. 9 E., southwest corner of sec. 2, 2 feet south and 2 feet west of southwest corner of crossroads; iron post stamped "1333 OMAHA"	1,334.472
Cook, in southeast corner of water table of Farmer's Bank; aluminum tablet stamped "1062 OMAHA"	1,061.622

Nebraska City Quadrangle.

CASS, NEMAHA, AND OTOE COUNTIES.

The elevations in the following list depend on a bench mark established by the Missouri River Commission 3,884 feet north of the railroad station at Nebraska City Junction, Iowa—a buried stone with copper bolt 3 feet underground, surmounted by an iron post with a cap terminating in a rounded knob, marked "Missouri River Commission." The accepted elevation of the top of the cap is 924.589 feet.

The leveling was done in 1905 by F. W. Hughes.

NEBRASKA CITY QUADRANGLE.

Point 2 miles west of Nebraska City Junction west to Nebraska City.

	Feet.
Nebraska City Junction, 2 miles west of, 40 feet south of crossing, 30 feet east of center of road; iron post stamped "923 ADJ 1903"	923.191
T. 8 N., R. 14 E., center of sec. 23, 460 feet west of railroad crossing, opposite bridge over Four Mile Creek; iron post stamped "927 ADJ 1903"	926.671
Minersville, near center of north line of sec. 12, T. 7 N., R. 14 E., northeast corner of church; iron post stamped "933 ADJ 1903"	932.406
Barney, near center of NE. ¼ sec. 30, T. 7 N., R. 15 E., 120 feet northwest of grain elevator; iron post stamped "913 ADJ 1903"	912.717
T. 7 N., R. 14 E., about center of south line of sec. 25, 200 feet northeast of bridge over Camp Creek, 2 feet southeast of 2-foot walnut and 20 feet southwest of 2-foot walnut at T road north; iron post stamped "929 ADJ 1903"	928.357
T. 6 N., R. 14 E., northeast corner of sec. 4, opposite Pleasant Valley schoolhouse; iron post stamped "1012 ADJ 1903"	1,011.482
Julian, southwest corner of SE. ¼ sec. 32, T. 7 N., R. 14 E., 100 feet north of center of road, opposite main street through Julian; iron post stamped "1041 ADJ 1903"	1,040.443

	Feet.
T. 6 N., R. 13 E., northwest corner of sec. 1, 30 feet south and 30 feet east of crossroads; iron post stamped "1152 ADJ 1903"	1,151.596
T. 6 N., R. 13 E., northwest corner of sec. 4, 40 feet south and 30 feet east of crossroads; iron post stamped "971 ADJ 1903"	971.064

Nebraska City north along Missouri Pacific Railway to point near Wyoming, thence west and south along highways via Sunnyside and Baker schoolhouses to sec. 4, T. 6 N., R. 13 E.

Nebraska City, at north entrance to post office, in second step above pavement, 1 foot east of building; aluminum tablet stamped "1030 ADJ 1903".	1,029.699
Walnut Creek Mills, 0.25 mile south of northwest corner of sec. 31, T. 9 N., R. 14 E., 600 feet south of Walnut Creek mills, 180 feet south of railroad crossing, 20 feet east of center of road; iron post stamped "999 ADJ 1903".	998.826
Wyoming, 250 feet south of station, in edge of orchard; iron post stamped "Prim. Trav. Sta. No. 8 1120 ADJ 1903"	1,119.803
T. 9 N., R. 13 E., northwest corner of NE. ¼ sec. 21, 40 feet south and 20 feet east of road forks; iron post stamped "1111 ADJ 1903"	1,110.610
Sunnyside schoolhouse, 0.8 mile west of, northwest corner of sec. 4, T. 8 N., R. 13 E., 20 feet south and 30 feet east of center of T road; iron post stamped "1218 ADJ 1903"	1,217.809
T. 8 N., R. 13 E., southeast corner of sec. 17, 20 feet west and 30 feet north of center of crossroads; iron post stamped "1150 ADJ 1903"	1,149.579
T. 7 N., R. 13 E., 50 feet south and 20 feet east of northwest corner of sec. 4; iron post stamped "1230 ADJ 1903"	1,229.417
T. 7 N., R. 13 E., northwest corner of sec. 21, 30 feet south and 30 feet east of center of crossroads; iron post stamped "1149 ADJ 1903"	1,148.708

Point 7 miles south of Baker schoolhouse west to sec. 23, T. 7 N., R. 12 E.

T. 7 N., R. 12 E., northwest corner of sec. 23, 20 feet east and 2 feet south of southeast corner road crossing; iron post stamped "982 OMAHA"	981.342

At Nebraska City.

Nebraska City, in front of Chicago, Burlington & Quincy R. R. station; top of rail	966.88

Browns Creek, Chappell, Gothenburg, North Platte, Ogalalla, Paxton, and Sidney Quadrangles.

ARTHUR, CHEYENNE, DAWSON, DEUEL, FRONTIER, KEITH, LINCOLN, LOGAN, AND M'PHERSON COUNTIES.

The elevations in the following list are only approximate, as they depend on the height of the Union Pacific R. R. bridge over Lodgepole Creek, near milepost 410. The railroad company's elevation of the bridge, derived from Omaha datum, is 4,016.12 feet.

The leveling in the Browns Creek quadrangle and in part of the Sidney quadrangle was done by H. M. Trippe in 1896; that in the Chappell and Ogalalla quadrangles and in the remainder of the Sidney quadrangle by Ross C. Cornish in 1897; that in the Paxton quadrangle by C. E. Hewitt in 1898; and that in the North Platte and Gothenburg quadrangles by E. E. Sands in 1899.

SIDNEY QUADRANGLE.

Bench marks established near public land corners.

	Feet.
T. 12 N., R. 46 W., southeast corner of sec. 9; iron post stamped "SIDNEY 3908"	3,908.216
T. 13 N., R. 45 W., southeast corner of sec. 30; iron post stamped "SIDNEY 3897"	3,897.384
T. 13 N., R. 46 W., southeast corner of sec. 2; iron post stamped "SIDNEY 3757"	3,757.233
T. 13 N., R. 46 W., southeast corner of sec. 27; iron post stamped "SIDNEY 3983"	3,982.950
T. 13 N., R. 47 W., southeast corner of sec. 25; iron post stamped "SIDNEY 4078"	4,077.901
T. 13 N., R. 47 W., southeast corner of sec. 33; iron post stamped "SIDNEY 4117"	4,117.222
T. 13 N., R. 48 W., southeast corner of sec. 25; iron post stamped "SIDNEY 4131"	4,131.229
T. 13 N., R. 48 W., southeast corner of sec. 34; iron post stamped "SIDNEY 4167"	4,167.252
T. 13 N., R. 48 W., southeast corner of sec. 22; iron post stamped "SIDNEY 4162"	4,162.220
T. 13 N., R. 48 W., northeast corner of sec. 3; iron post stamped "SIDNEY 4013"	4,013.457
Lodgepole, T. 14 N., R. 46 W., sec. 30, stone monument in park; bronze tablet stamped "SIDNEY 3833"	3,832.755
T. 14 N., R. 47 W., southeast corner of sec. 12; iron post stamped "SIDNEY 4011"	4,011.418
T. 14 N., R. 47 W., west side of sec. 27, on main line Union Pacific Railroad; iron post stamped "SIDNEY 3878"	3,878.088
T. 14 N., R. 47 W., sec. 30, near milepost 403, Sunol switch; iron post stamped "SIDNEY 3921"	3,921.025
T. 15 N., R. 47 W., southeast corner of sec. 26; iron post stamped "SIDNEY 3913"	3,913.356
T. 15 N., R. 47 W., southeast corner of sec. 28; iron post stamped "SIDNEY 3960"	3,960.192
T. 15 N., R. 46 W., southwest corner of sec. 27; iron post stamped "SIDNEY 3928"	3,928.099
T. 15 N., R. 46 W., southeast corner of sec. 25; iron post stamped "SIDNEY 3896"	3,896.123
T. 15 N., R. 46 W., quarter corner on east side of sec. 13; iron post stamped "SIDNEY 3885"	3,884.953
T. 16 N., R. 46 W., southeast corner of sec. 36; iron post stamped "SIDNEY 3933"	3,933.187
T. 13 N., R. 49 W., southeast corner of sec. 7; iron post stamped "4284"	4,284.262
T. 13 N., R. 49 W., southeast corner of sec. 30; iron post stamped "4288"	4,288.272
T. 13 N., R. 49 W., southeast corner of sec. 36; iron post stamped "4233"	4,233.829
Sidney, T. 14 N., R. 49 W., Union Pacific R. R. station; doorsill of ladies' waiting room	4,093.540
Fort Sidney, T. 14 N., R. 49 W., in astronomical monument in parade ground; copper bolt stamped "4086"	4,086.279
T. 14 N., R. 49 W., near southwest corner sec. 25; iron post stamped "4025"	4,025.083
T. 14 N., R. 48 W., sec. 29, northwest corner stone in foundation of schoolhouse; copper bolt stamped "4015"	4,015.395
T. 14 N., R. 48 W., southeast corner of sec. 7; iron post stamped "4165"	4,165.415

	Feet.
T. 15 N., R. 49 W., sec. 28; iron post stamped "4226"	4,226.447
T. 15 N., R. 49 W., southeast corner of sec. 13; iron post stamped "4190"	4,189.761
T. 15 N., R. 48 W. southeast corner of sec. 6; iron post stamped "4163"	4,162.851
T. 16 N., R. 49 W., southeast corner of sec. 26; iron post stamped "4194"	4,194.088
T. 16 N., R. 48 W., in wall of schoolhouse in northwest corner of sec. 26; bronze tablet stamped "4122"	4,121.645
T. 16 N., R. 48 W., southeast corner of sec. 11; iron post stamped "4109"	4,108.898
T. 16 N., R. 47 W., southeast corner of sec. 8; iron post stamped "4030"	4,030.328
T. 16 N., R. 47 W., southwest corner of sec. 12; iron post stamped "3993"	3,992.736
T. 17 N., R. 49 W., southeast corner of sec. 32; iron post stamped "4281"	4,280.795
T. 17 N., R. 49 W., southeast corner of sec. 36; iron post stamped "4202"	4,202.643
T. 17 N., R. 48 W., southeast corner of sec. 21; iron post stamped "4145"	4,144.664
T. 17 N., R. 47 W., northwest corner of sec. 30, in southeast corner of schoolhouse; bronze tablet stamped "4101"	4,101.046
T. 17 N., R. 47 W., southeast corner of sec. 31; iron post stamped "4041"	4,040.734
T. 18 N., R. 49 W., sec. 34, North's ranch; iron post stamped "3898"	3,897.670
T. 18 N., R. 48 W., sec. 26, Radcliffe's ranch; iron post stamped "3728"	3,728.256
T. 18 N., R. 46 W., sec. 31, Hanna's ranch; iron post stamped "3509"	3,509.253
T. 17 N., R. 46 W., NW. ¼ sec. 4, north side of river road; iron post stamped "3542"	3,541.944
T. 17 N., R. 46 W., near center of sec. 12, at crossroads; iron post stamped "3477"	3,476.839
T. 17 N., R. 45 W., at gate on road near northeast corner of section 30; iron post stamped "3504"	3,503.667
T. 16 N., R. 46 W., at forks of road near southeast corner of section 2; iron post stamped "3608"	3,608.215
T. 16 N., R. 46 W., at gate on road near east side of section 27; iron post stamped "3689"	3,688.629

BROWNS CREEK QUADRANGLE.

Bench marks established near public-land corners.

T. 18 N., R. 49 W., southeast corner of SW. ¼ sec. 3; iron post stamped "3699"	3,698.789
T. 18 N., R. 48 W., on river road near northwest corner of sec. 11; iron post stamped "3564"	3,564.177
T. 18 N., R. 47 W., east side of sec. 19, southeast corner of Nichol's house; tablet stamped "3613"	3,612.762
T. 18 N., R. 47 W., NE. ¼ sec. 5, Ramsburg's ranch; iron post stamped "3545"	3,544.951
Belmont, near northeast corner sec. 18, T. 19 N., R. 49 W.; iron post stamped "3638"	3,638.225
T. 19 N., R. 49 W., southeast corner of NE. ¼ sec. 14 (Bearline's ranch); iron post stamped "3613"	3,613.211
T. 19 N., R. 49 W., southeast corner of sec. 30; iron post stamped "3596"	3,596.147
T. 19 N., R. 48 W., south side of sec. 27, Carl Wagner's ranch; iron post stamped "3577"	3,577.259
T. 19 N., R. 47 W., near southwest corner of sec. 16, 3.25 miles north of Remsburg's ranch, forks of road; iron post stamped "4044"	4,044.274
T. 19 N., R. 47 W., southeast corner of NE. ¼ sec. 25; iron post stamped "4025"	4,024.604
T. 20 N., R. 49 W., southwest corner of sec. 32; iron post stamped "3689"	3,689.198
T. 20 N., R. 49 W., southeast corner of sec. 36; iron post stamped "3727"	3,727.331

	Feet.
T. 20 N., R. 48 W., NW. ¼ sec. 19, Delano's ranch; iron post stamped "3902"	3,902.152
T. 20 N., R. 47 W., SW. ¼ sec. 7, at crossroads; iron post stamped "4239"	4,238.846
T. 20 N., R. 47 W., sec. 32, at side of road, between Remsburg's and Hibler's ranches; iron post stamped "4099"	4,099.361
T. 21 N., R. 49 W., near north side of sec. 12, crossroads; iron post stamped "4135"	4,134.906
T. 21 N., R. 49 W., near north side of sec. 26, forks of road; iron post stamped "4370"	4,370.150
T. 21 N., R. 48 W., sec. 9, Peer's ranch; iron post stamped "4041"	4,040.543
T. 21 N., R. 48 W., sec. 13, Haine's ranch; iron post stamped "4018"	4,017.769
T. 21 N., R. 47 W., SW. ¼ sec. 4 (error in General Land Office work; this should be SW. ¼ sec. 3), J. W. Rodger's ranch; iron post stamped "3946"	3,945.612
T. 21 N., R. 47 W., southwest corner of sec. 28, Hibler's ranch; iron post stamped "3989"	3,988.979
T. 21 N., R. 46 W., sec. 8, Margesson's ranch; iron post stamped "3897"	3,896.956
T. 22 N., R. 49 W., by side of Alliance road, near north side of sec. 2; iron post stamped "4117"	4,116.682
T. 22 N., R. 49 W., SE. ¼ sec. 27, at forks of road; iron post stamped "4125"	4,124.45
T. 22 N., R. 48 W., NE. ¼ sec. 1, at side of road; iron post stamped "3977"	3,977.447
T. 22 N., R. 48 W., NE. ¼ sec. 27, at forks of road; iron post stamped "4040"	4,039.822
T. 22 N., R. 47 W., SE. ¼ sec. 21, southwest side of Alliance road; iron post stamped "3955"	3,954.693
T. 22 N., R. 47 W., northeast corner of sec. 1; iron post stamped "3901"	3,900.592
T. 23 N., R. 49 W., near northwest corner of sec. 14, Rall's ranch; iron post stamped "4093"	4,092.374
T. 23 N., R. 49 W., near center of sec. 25, Johnson's ranch; anchor of gate south of house	4,060.9
T. 23 N., R. 49 W., SE. ¼ sec. 12, James's ranch; top of southeast anchor post of windmill tower	4,043
T. 23 N., R. 48 W., sec. 17, Fleet's ranch; iron post stamped "4026"	4,026.143
T. 23 N., R. 48 W., northeast corner of sec. 3; iron post stamped "3969"	3,969.078
T. 23 N., R. 47 W., near southeast corner of sec. 29, 20 feet north of crossroads, 0.8 mile west from Smith's ranch; west anchor of gate	3,966.9
T. 23 N., R. 47 W., near east side of sec. 28, south side of gate on road from Smith's ranch to Hague's ranch; iron post stamped "3950"	3,949.923
T. 23 N., R. 46 W., sec. 29, at crossroads south of Wild Horse Lake; iron post stamped "3901"	3,901.116
T. 23 N., R. 46 W., near southwest corner of sec. 24, at side of Alliance road; iron post stamped "3890"	3,890.078
T. 23 N., R. 45 W., near east side of section 17, Hill's ranch; iron post stamped "3886"	3,886.347
T. 22 N., R. 46 W., SE. ¼ sec. 4, at forks of road; iron post stamped "3895"	3,895.482
T. 22 N., R. 46 W., near south line of sec. 13, at forks of road; iron post stamped "3878"	3,878.259
T. 22 N., R. 45 W., near northwest corner sec. 34, Hubble's ranch; iron post stamped "3856"	3,855.703
T. 21 N., R. 46 W., near center of S. ½ sec. 1, at crossroads; iron post stamped "3865"	3,864.729
T. 21 N., R. 45 W., NW. ¼ sec. 29, Orlando post office; iron post stamped "3854"	3,854.115
T. 20 N., R. 46 W., SE. ¼ sec. 3, Slater's ranch; iron post stamped "3872"	3,872.398
T. 20 N., R. 46 W., near center of sec. 22; Richardson's ranch; iron post stamped "3866"	3,865.895

	Feet.
T. 20 N., R. 45 W., near center of N. ½ sec. 17, at bend in road southeast of Twin Lakes; iron post stamped "3815"	3,814.691
T. 19 N., R. 46 W., E. ½ sec. 11, in sand hills, at forks of road just south of Blowout; iron post stamped "3881"	3,881.624
T. 19 N., R. 46 W., near center of sec. 23, at side of road; iron post stamped "3948"	3,948.043
T. 19 N., R. 45 W., southeast corner of SW. ¼ sec. 31; iron post stamped "3952"	3,952.091
T. 18 N., R. 46 W., NW. ¼ sec. 10, south edge of terrace on side of road; iron post stamped "3977"	3,977.165
T. 18 N., R. 45 W., southeast corner of sec. 17; iron post stamped "3935"	3,935.007

CHAPPELL QUADRANGLE.

Bench marks established near public-land corners.

T. 12 N., R. 45 W., in section 21 on Nebraska-Colorado State line, 0.5 mile west of Lodgepole Creek; iron post stamped "SIDNEY 3591"	3,590.886
T. 12 N., R. 42 W., sec. 6, milepost 365, Union Pacific R. R., iron post stamped "SIDNEY 3413"	3,413.057
T. 13 N., R. 41 W., sec. 27, milepost 357, Union Pacific R. R.; iron post stamped "SIDNEY 3341"	3,340.735
Bigsprings, southeast corner of sec. 25, T. 13 N., R. 42 W.; iron post stamped SIDNEY 3370"	3,370.061
T. 13 N., R. 42 W., southeast corner of sec. 1; iron post stamped "SIDNEY 3613"	3,613.028
T. 13 N., R. 42 W., quarter corner on south side of sec. 17; iron post stamped "SIDNEY 3592"	3,591.778
T. 13 N., R. 43 W., quarter corner on south side of sec. 14; iron post stamped "SIDNEY 3648"	3,647.963
T. 13 N., R. 43 W., southeast corner of sec. 18; iron post stamped "SIDNEY 3717"	3,717.196
T. 13 N., R. 44 W., southeast corner of sec. 10; iron post stamped "SIDNEY 3793"	3,793.021
T. 13 N., R. 44 W., sec. 31, milepost 383, Union Pacific Railroad; iron post stamped "SIDNEY 3636"	3,635.921
Chappell; railroad station, sec. 15, T. 13 N., R. 45 W.; iron post stamped "SIDNEY 3696"	3,696.084
T. 14 N., R. 42 W., southeast corner of sec. 13; iron post stamped "SIDNEY 3652"	3,651.791
T. 14 N., R. 42 W., southeast corner of sec. 3; iron post stamped "SIDNEY 3694"	3,694.097
T. 14 N., R. 42 W., southeast corner of sec. 6; iron post stamped "SIDNEY 3723"	3,722.121
T. 14 N., R. 43 W., southeast corner of sec. 10; iron post stamped "SIDNEY 3764"	3,764.154
T. 14 N., R. 43 W., southeast corner of sec. 7; iron post stamped "SIDNEY 3768"	3,767.974
T. 14 N., R. 44 W., southeast corner of sec. 27; iron post stamped "SIDNEY 3804"	3,804.321
T. 14 N., R. 44 W., southeast corner of sec. 10; iron post stamped "SIDNEY 3796"	3,796.152
T. 14 N., R. 45 W., southeast corner of sec. 2; iron post stamped "SIDNEY 3874"	3,874.043
T. 14 N., R. 45 W., southeast corner of sec. 5; iron post stamped "SIDNEY 3916"	3,916.072

	Feet.
T. 15 N., R. 42 W., southeast corner of sec. 36; iron post stamped "SIDNEY 3739"	3,739.322
T. 15 N., R. 42 W., sec. 26, forks of wagon road; iron post stamped "SIDNEY 3763"	3,763.153
T. 15 N., R. 42 W., sec. 3, mouth of Ash Hollow, near Rachael Patterson's grave; iron post stamped "SIDNEY 3314"	3,314.206
T. 15 N., R. 43 W., southeast corner of sec. 27; iron post stamped "SIDNEY 3729"	3,728.662
T. 15 N., R. 43 W., southeast corner of sec. 30; iron post stamped "SIDNEY 3833"	3,833.220
T. 15 N., R. 44 W., southeast corner of sec. 27; iron post stamped "SIDNEY 3792"	3,792.15
T. 15 N., R. 44 W., southeast corner of sec. 30; iron post stamped "SIDNEY 3829"	3,829.382
T. 15 N., R. 45 W., southeast corner of sec. 27; iron post stamped "SIDNEY 3923"	3,923.068
T. 16 N., R. 41 W., southeast corner of sec. 30; iron post stamped "SIDNEY 3309"	3,308.466
T. 16 N., R. 42 W., southeast corner of sec. 12; iron post stamped "SIDNEY 3593"	3,592.772
T. 16 N., R. 42 W., southeast corner of sec. 27; iron post stamped "SIDNEY 3304"	3,304.008
T. 16 N., R. 42 W., sec. 31, near mouth of ravine; iron post stamped "SIDNEY 3357"	3,356.959
T. 16 N., R. 43 W., quarter corner on east side of sec. 22; iron post stamped "SIDNEY 3332"	3,331.748
T. 16 N., R. 43 W., sec. 18, Charles Simpson's ranch; iron post stamped "SIDNEY 3365"	3,364.230
T. 16 N., R. 44 W., quarter corner on east side of sec. 10; iron post stamped "SIDNEY 3393"	3,392.674
T. 16 N., R. 44 W., near northeast corner of sec. 5, south bank North Platte River; iron post stamped "SIDNEY 3427"	3,426.700
T. 17 N., R. 41 W., southwest corner of sec. 31; iron post stamped "SIDNEY 3628"	3,628.244
T. 17 N., R. 41 W., near southeast corner of sec. 34, on wagon road; iron post stamped "SIDNEY 3632"	3,631.775
T. 17 N., R. 42 W., SW. ¼ sec. 29, side of wagon road; iron post stamped "SIDNEY 3643"	3,642.903
T. 17 N., R. 42 W., NE. ¼ sec. 18, road crossing; iron post stamped "SIDNEY 3741"	3,740.829
T. 17 N., R. 43 W., quarter corner on south side of sec. 11; iron post stamped "SIDNEY 3710"	3,709.258
T. 17 N., R. 43 W., southwest corner of sec. 8; iron post stamped "SIDNEY 3720"	3,719.491
T. 17 N., R. 44 W., southwest corner of sec. 32; iron post stamped "SIDNEY 3455"	3,455.088
T. 17 N., R. 44 W., southwest corner of sec. 24; iron post stamped "SIDNEY 3428"	3,427.794
T. 17 N., R. 44 W., southwest corner of sec. 1; iron post stamped "SIDNEY 3601"	3,600.520
T. 17 N., R. 45 W., sec. 23, Coumbe's ranch; iron post stamped "SIDNEY 3423"	3,422.450
Hartmann, sec. 34, T. 18 N., R. 44 W.; iron post stamped "SIDNEY 3595"	3,595.077

OGALALLA QUADRANGLE.

Bench marks established near public land corners.

	Feet.
Ogalalla, railroad station, sec. 6, T. 13 N., R. 38 W.; iron post stamped "SIDNEY 3216"	3,215.884
T. 13 N., R. 39 W., sec. 11, at Union Pacific. R. R. milepost 344; iron post stamped "SIDNEY 3242"	3,242.138
T. 13 N., R. 39 W., sec. 17; at Union Pacific R. R. milepost 347; iron post stamped "SIDNEY 3265"	3,265.151
Brule, sec. 15, T. 13 N., R. 40 W.; iron post stamped "SIDNEY 3291"	3,290.766
T. 13 N., R. 40 W., sec. 19, at Union Pacific R. R. milepost 354; iron post stamped "SIDNEY 3333"	3,333.172
T. 14 N., R. 39 W., near southeast corner of sec. 13; forks of road; iron post stamped "SIDNEY 3533"	3,533.079
T. 14 N., R. 39 W., quarter corner on east side of sec. 32; iron post stamped "SIDNEY 3489"	3,488.754
T. 14 N., R. 40 W., southeast corner of sec. 14; iron post stamped "SIDNEY 3653"	3,653.213
T. 14 N., R. 40 W., quarter corner on south side of sec. 17; iron post stamped "SIDNEY 3579"	3,578.688
T. 14 N., R. 41 W., southeast corner of sec. 15; iron post stamped "SIDNEY 3712"	3,712.077
T. 15 N., R. 37 W., southeast corner of sec. 31; iron post stamped "SIDNEY 3107"	3,106.813
T. 15 N., R. 37 W., NW. ¼ sec. 6; iron post stamped "SIDNEY 3373"	3,373.345
T. 15 N., R. 38 W., NW. ¼ sec. 13; iron post stamped "SIDNEY 3306"	3,306.111
T. 15 N., R. 38 W., southeast corner of sec. 30; iron post stamped "SIDNEY 3146"	3,145.921
T. 15 N., R. 39 W., sec. 26, at schoolhouse; iron post stamped "SIDNEY 3161"	3,161.352
T. 15 N., R. 39 W., southeast corner of sec. 20; iron post stamped "SIDNEY 3184"	3,183.873
T. 15 N., R. 40 W., southeast corner of sec. 11; iron post stamped "SIDNEY 3216"	3,216.144
T. 15 N., R. 40 W., sec. 6, at Fairchild's ranch; iron post stamped "SIDNEY 3233"	3,233.232
T. 16 N., R. 37 W., southeast corner of sec. 20, near Mannon's ranch; iron post stamped "SIDNEY 3435"	3,435.088
T. 16 N., R. 37 W., S. ½ sec. 8; iron post stamped "SIDNEY 3472"	3,472.029
T. 16 N., R. 38 W., S. ½ sec. 26, by side of wagon road; iron post stamped "SIDNEY 3430"	3,430.175
T. 16 N., R. 38 W., SE. ¼ sec. 9, by side of wagon road in Wild Horse Valley; iron post stamped "SIDNEY 3485"	3,484.798
T. 16 N., R. 39 W., S. ½ sec. 2, at side of wagon road; iron post stamped "SIDNEY 3520"	3,520.056
T. 16 N., R. 39 W., near center of sec. 16, at junction of wagon roads; iron post stamped "SIDNEY 3523"	3,523.032
T. 16 N., R. 40 W., NE. ¼ sec. 36, Winslow's ranch; iron post stamped "SIDNEY 3405"	3,404.659
T. 16 N., R. 40 W., southeast corner of sec. 13; iron post stamped "SIDNEY 3529"	3,529.104
T. 17 N., R. 37 W., SW. ¼ sec. 27, at side of wagon road in valley; iron post stamped "SIDNEY 3490"	3,490.013

	Feet.
T. 17 N., R. 37 W., west side of sec. 10, at side of road in valley; iron post stamped "SIDNEY 3504"	3,504.235
T. 17 N., R. 38 W., SE. ¼ sec. 29, at side of road in valley; iron post stamped "SIDNEY 3533"	3,533.370
T. 17 N., R. 38 W., east side of sec. 6, in small valley; iron post stamped "SIDNEY 3588"	3,587.711
T. 17 M., R. 39 W., NE. ¼ sec. 23, at forks of wagon road; iron post stamped "SIDNEY 3575"	3,574.886
T. 17 N., R. 39 W., SE. ¼ sec. 4, at side of wagon road in valley; iron post stamped "SIDNEY 3612"	3,611.980
T. 17 N., R. 40 W., SE. ¼ sec. 36, at north end of valley; iron post stamped "SIDNEY 3564"	3,564.185

PAXTON QUADRANGLE.

Bench marks established near public land corners.

T. 12 N., R. 36 W., southeast corner of sec. 5; iron post stamped "SIDNEY 3279"	3,278.980
T. 12 N., R. 36 W., southeast corner of sec. 36; iron post stamped "SIDNEY 3244"	3,244.348
T. 12 N., R. 35 W., southeast corner of sec. 12; iron post stamped "SIDNEY 3203"	3,202.947
T. 12 N., R. 34 W., southeast corner of sec. 12; iron post stamped "SIDNEY 3183"	3,183.178
T. 12 N., R. 33 W., near corner of sec. 13; iron post stamped "SIDNEY 3158"	3,158.217
T. 13 N., R. 35 W., southeast corner of sec. 30; iron post stamped "SIDNEY 3220"	3,220.358
T. 13 N., R. 34 W., southeast corner of sec. 30; iron post stamped "SIDNEY 3166"	3,166.122
T. 13 N., R. 33 W., southeast corner of sec. 30; iron post stamped "SIDNEY 3138"	3,138.387
T. 13 N., R. 32 W., southeast corner of sec. 18; iron post stamped "SIDNEY 3116"	3,116.445
T. 13 N., R. 34 W., southeast corner of sec. 7; iron post stamped "SIDNEY 3114"	3,113.978
T. 13 N., R. 33 W., southeast corner of sec. 6; iron post stamped "SIDNEY 3016"	3,015.914
T. 14 N., R. 36 W., near quarter corner on south side of sec. 6; iron post stamped "SIDNEY 3090"	3,089.620
T. 14 N., R. 35 W., near center of sec. 5; iron post stamped "SIDNEY 3322"	3,322.228
T. 14 N., R. 36 W., near center of sec. 24, on south side North Platte River; iron post stamped "SIDNEY 3082"	3,081.521
T. 14 N., R. 35 W., quarter corner on east side of sec. 30; iron post stamped "SIDNEY 3067"	3,067.224
T. 14 N., R. 34 W., northeast corner of sec. 6; iron post stamped "SIDNEY 3138"	3,138.266
T. 14 N., R. 34 W., northwest corner of sec. 30; iron post stamped "SIDNEY 3021"	3,020.537
T. 14 N., R. 33 W., southeast corner of sec. 17; iron post stamped "SIDNEY 2989"	2,989.402
T. 14 N., R. 34 W., southeast corner of sec. 18; iron post stamped "SIDNEY 2913"	2,912.698

	Feet.
T. 14 N., R. 36 W., sec. 24, south bank of North Platte River in south edge of grove; iron post stamped "SIDNEY 3032"	3,031.521
T. 15 N., R. 36 W., near quarter corner on east side of sec. 6; iron post stamped "SIDNEY 3421"	3,420.600
T. 15 N., R. 36 W., NE. ¼ sec. 30; iron post stamped "SIDNEY 3284"	3,283.600
T. 15 N., R. 35 W., near center of sec. 6; iron post stamped "SIDNEY 3332"	3,331.566
T. 15 N., R. 35 W., southeast corner of sec. 30; iron post stamped "SIDNEY 3248"	3,247.703
T. 15 N., R. 34 W., SE. ¼ sec. 6; iron post stamped "SIDNEY 3320"	3,320.304
T. 15 N., R. 34 W., NE. ¼ sec. 19; iron post stamped "SIDNEY 3291"	3,291.146
T. 15 N., R. 33 W., near center of sec. 5; iron post stamped "SIDNEY 3130"	3,129.963
T. 15 N., R. 33 W., NE. ¼ sec. 20; iron post stamped "SIDNEY 3129"	3,128.815
T. 15 N., R. 33 W., near quarter corner on south side of sec. 32; iron post stamped "SIDNEY 2992"	2,991.929
T. 15 N., R. 32 W., near southeast corner of sec. 6; iron post stamped "SIDNEY 3162"	3,161.565
T. 15 N., R. 32 W., near center of sec. 7; iron post stamped "SIDNEY 3102"	3,101.565
T. 15 N., R. 32 W., near quarter corner on south side of sec. 31; iron post stamped "SIDNEY 2915"	2,915.289
T. 16 N., R. 36 W., near quarter corner on west side of sec. 20; iron post stamped "SIDNEY 3464"	3,464.186
T. 16 N., R. 36 W., near southwest corner of sec. 3; iron post stamped "SIDNEY 3454"	3,453.716
T. 16 N., R. 35 W., near quarter corner on west side of sec. 18; iron post stamped "SIDNEY 3381"	3,380.548
T. 16 N., R. 34 W., near southeast corner of sec. 7; iron post stamped "SIDNEY 3314"	3,313.719
T. 16 N., R. 33 W., NW. ¼ sec. 18; iron post stamped "SIDNEY 3148"	3,148.062
T. 16 N., R. 32 W., near quarter corner on east side of sec. 17; iron post stamped "SIDNEY 3182"	3,182.342
T. 17 N., R. 36 W., NW. ¼ sec. 3; iron post stamped "SIDNEY 3474"	3,474.042
T. 17 N., R. 36 W., near southwest corner of sec. 23; iron post stamped "SIDNEY 3450"	3,449.628
T. 17 N., R. 35 W., SW. ¼ sec. 4; iron post stamped "SIDNEY 3411"	3,410.538
T. 17 N., R. 35 W., near center of sec. 32; iron post stamped "SIDNEY 3450"	3,449.760
T. 17 N., R. 34 W., NE. ¼ sec. 20; iron post stamped "SIDNEY 3319"	3,318.592
T. 17 N., R. 34 W., SW. ¼ sec. 33; iron post stamped "SIDNEY 3371"	3,371.066
T. 17 N., R. 34 W., NE. ¼ sec. 12; iron post stamped "SIDNEY 3285"	3,285.013
T. 17 N., R. 33 W., near quarter corner on north side of sec. 4; iron post stamped "SIDNEY 3262"	3,262.336
T. 17 N., R. 33 W., near center of sec. 1; iron post stamped "SIDNEY 3236"	3,236.430
T. 17 N., R. 32 W., near northwest corner of sec. 31; iron post stamped "SIDNEY 3118"	3,117.967
T. 17 N., R. 32 W., near northeast corner of sec. 17; iron post stamped "SIDNEY 3264"	3,263.853
T. 18 N., R. 35 W., near center of sec. 33; iron post stamped "SIDNEY 3421"	3,421.241
T. 18 N., R. 34 W., SW. ¼ sec. 30; iron post stamped "SIDNEY 3353"	3,352.535

NORTH PLATTE QUADRANGLE.

Spuds east along Union Pacific Railroad to Maxwell.

Feet.

Spuds, east end of stock yards; iron post stamped "SIDNEY 2852"...... 2,852.446

North Platte, foundation of front steps, First National Bank; aluminum tablet stamped "SIDNEY 2805"........ 2,805.049

Milepost "287 Miles West of Omaha," quarter mile west of; iron post stamped "SIDNEY 2779"........ 2,779.500

Gannett, at Union Pacific signpost; iron post stamped "SIDNEY 2769"... 2,769.022

Pawnee, near east end of switch; iron post stamped "SIDNEY 2747"... 2,747.203

Farnam, 1,248.7 feet west of center of bridge 20 and 16.7 feet south at right angles from center of main track, in Depot Park, at west line of Broad Street; iron post stamped "SIDNEY 2729"........ 2,729.024

Maxwell, west end of station; iron post stamped "SIDNEY 2714"....... 2,714.457
(In 1910 permission was granted to move this to a new location. No record of the transfer has yet been received.)

Bench marks established near public land corners.

T. 12 N., R. 30 W., SE. ¼ sec. 5, on main road south from North Platte; iron post stamped "SIDNEY 3067"........ 3,066.926

T. 12 N., R. 29 W., sec. 18, west of schoolhouse on main road to North Platte; iron post stamped "SIDNEY 3056"........ 3,056.047

T. 12 N., R. 28 W., sec. 5, south end of Platte River bridge; iron post stamped "SIDNEY 2714"........ 2,714.485

T. 12 N., R. 31 W., NE. ¼ sec. 3; iron post stamped "SIDNEY 3028"..... 3,028.230

T. 12 N., R. 29 W., NE. ¼ sec. 13, in Boxelder Canyon; iron post stamped "SIDNEY 2786"........ 2,785.601

T. 13 N., R. 28 W., north side of sec. 3, on Maxwell wagon road; iron post stamped "SIDNEY 2888"........ 2,888.475

T. 13 N., R. 30 W., sec. 21, on main road south from North Platte, near woven wire fence; iron post stamped "SIDNEY 2822" (this bench mark has been moved 10 feet south from its original position; the elevation has not been changed)........ 2,822.211

T. 13 N., R. 31 W., sec. 24, on road running west from Platte River bridge; iron post stamped "SIDNEY 2833"........ 2,833.450

T. 14 N., R. 29 W., NE. ¼ sec. 30, in valley northwest of white schoolhouse, iron post stamped "SIDNEY 2822"........ 2,821.754

T. 14 N., R. 28 W., near north side of sec. 27; iron post stamped "SIDNEY 2866"........ 2,866.912

T. 14 N., R. 28 W., SW. ¼ sec. 2; iron post stamped "SIDNEY 2912"..... 2,911.744

T. 15 N., R. 28 W., SW. ¼ sec. 23; iron post stamped "SIDNEY 2954"...... 2,953.659

T. 15 N., R. 28 W., NW. ¼ sec. 2, near house; iron post stamped "SIDNEY 3000"........ 2,999.632

T. 15 N., R. 31 W., sec. 22, west of schoolhouse; iron post stamped "SIDNEY 2930"........ 2,930.106

T. 15 N., R. 29 W., SE. ¼ sec. 5, on old stage road; iron post stamped "SIDNEY 2999"........ 2,999.338

T. 15 N., R. 29 W., NE. ¼ sec 18, on old stage road; iron post stamped "SIDNEY 3053"........ 3,053.330

T. 15 N., R. 30 W., southeast corner of sec. 34; iron post stamped "SIDNEY 2978"........ 2,978.133

T. 15 N., R. 31 W., NE. ¼ sec. 7, on old north-south wagon road; iron post stamped "SIDNEY 3087"........ 3,086.543

T. 15 N., R. 31 W., southwest corner of sec. 16; iron post stamped "SIDNEY 3075"........ 3,075.231

	Feet.
T. 15 N., R. 30 W., sec. 19, at Ellis schoolhouse; iron post stamped "SIDNEY 2946"	2, 945. 822
T. 16 N., R. 29 W., east side of sec. 22, near red schoolhouse; iron post stamped "SIDNEY 3038"	3, 037. 880
T. 16 N., R. 31 W., near center of sec. 9; iron post stamped "SIDNEY 3127"	3, 127. 329
T. 16 N., R. 31 W., NE. ¼ sec. 33; iron post stamped "SIDNEY 3139"	3, 138. 549
T. 16 N., R. 28 W., near quarter corner on south side of sec. 22; iron post stamped "SIDNEY 3012"	3, 011. 586
Myrtle, T. 16 N., R. 29 W., sec. 12; iron post stamped "SIDNEY 3049"	3, 049. 452
T. 16 N., R. 28 W., SE. ¼ sec. 8; iron post stamped "SIDNEY 3035"	3, 035. 205
T. 16 N., R. 30 W., SW. ¼ sec. 10, on road north from Ellis ranch; iron post stamped "SIDNEY 3105"	3, 104. 870
T. 16 N., R. 30 W., sec. 21, on road north from Ellis ranch; iron post stamped "SIDNEY 3077"	3, 077. 258
T. 16 N., R. 30 W., south side of sec. 31, on road north from Ellis ranch; iron post stamped "SIDNEY 3043"	3, 043. 281
T. 17 N., R. 28 W., sec. 35, road crossing on line between Logan and Lincoln Counties; iron post stamped "SIDNEY 3002"	3, 001. 950
T. 17 N., R. 29 W., quarter corner on east side of sec. 1; iron post stamped "SIDNEY 2960"	2, 960. 470
T. 17 N., R. 29 W., NE. ¼ sec. 10, near Chapin's house; iron post stamped "SIDNEY 2974"	2, 974. 350
T. 17 N., R. 31 W., sec. 8, crossroads east of Newberry's ranch; iron post stamped "SIDNEY 3200"	3, 200. 253
T. 17 N., R. 31 W., SW. ¼ sec. 34, near top of high hill on road from Seely post office to Newberry's ranch; iron post stamped "SIDNEY 3183"	3, 182. 615
T. 17 N., R. 30 W., NE. ¼ sec. 1, 0.5 mile north of Clothier's house; iron post stamped "SIDNEY 3066"	3, 066. 100
T. 17 N., R. 30 W., northwest corner of sec. 36; iron post stamped "SIDNEY 3141"	3, 141. 424
T. 18 N., R. 28 W., SW. ¼ sec. 35; iron post stamped "SIDNEY 2946"	2, 945. 770
T. 18 N., R. 28 W., southeast corner of sec. 32; iron post stamped "SIDNEY 2947"	2, 946. 832
T. 18 N., R. 29 W., near southwest corner of sec. 34; iron post stamped "SIDNEY 3019"	3, 019. 280
T. 18 N., R. 30 W., sec. 33; iron post stamped "SIDNEY 3168"	3, 167. 599
T. 18 N., R. 31 W., NW. ¼ sec. 33, on road north from Newberry's ranch; iron post stamped "SIDNEY 3232"	3, 231. 849

GOTHENBURG QUADRANGLE.

Bench marks established near public land corners.

T. 6 N., R. 24 W., northwest corner of sec. 6; iron post stamped "SIDNEY 2563"	2, 562. 895
T. 6 N., R. 25 W., northeast corner of sec. 4; iron post stamped "SIDNEY 2592"	2, 591. 955
T. 6 N., R. 26 W., northeast corner of sec. 5; iron post stamped "SIDNEY 2551"	2, 550. 925
T. 6 N., R. 27 W., NE. ¼ sec. 4, on road south from Stockville, near township line; iron post stamped "SIDNEY 2482"	2, 482. 453
T. 6 N., R. 28 W., northeast corner of sec. 1; iron post stamped "SIDNEY 2672"	2, 671. 513
T. 7 N., R. 24 W., quarter corner on north side of sec. 6; iron post stamped "SIDNEY 2668"	2, 667. 895

	Feet.
T. 7 N., R. 25 W., southeast corner of sec. 13; iron post stamped "SIDNEY 2527"	2,526.900
T. 7 N., R. 25 W., southeast corner of sec. 15; iron post stamped "SIDNEY 2636"	2,635.898
T. 7 N., R. 26 W., southeast corner of sec. 12; iron post stamped "SIDNEY 2674"	2,673.852
T. 7 N., R. 26 W., southeast corner of sec. 17; iron post stamped "SIDNEY 2650"	2,650.135
T. 7 N., R. 27 W., south side of sec. 11, on wagon road at divide between Mitchell and Medicine Creek canyons; iron post stamped "SIDNEY 2705"	2,704.661
Ingham, 293 feet west of center of railroad water tank, 318.5 feet east of center of bridge 28, 114.5 feet at right angles from center of main track; iron post stamped "SIDNEY" 2679	2,678.796
T. 7 N., R. 27 W., near northeast corner of sec. 4, on wagon road between Moorefield and Stockville; iron post stamped "SIDNEY 2671"	2,671.369
T. 7 N., R. 27 W., sec. 24, on wagon road at divide between Mitchell and Medicine creeks; iron post stamped "SIDNEY 2677"	2,677.083
T. 7 N., R. 27 W., north side of sec. 30; iron post stamped "SIDNEY 2638"	2,637.513
Stockville courthouse; iron post stamped "SIDNEY 2482"	2,482.451
T. 7 N., R. 28 W., SW. ¼ sec. 11; iron post stamped "SIDNEY 2733"	2,732.561
T. 8 N., R. 26 W., quarter corner on south side of sec. 10; iron post stamped "SIDNEY 2818"	2,817.937
Farnam, in front of railroad station; iron post stamped "SIDNEY 2729"	2,729.024
T. 8 N., R. 26 W., NE. ¼ sec. 3, in foundation of Curtis ranch house; aluminum tablet stamped "SIDNEY 2770"	2,769.851
T. 8 N., R. 24 W., near northeast corner of sec. 2, on line between Frontier and Dawson counties; iron post stamped "SIDNEY 2743"	2,742.590
T. 8 N., R. 25 W., south side of sec. 12, on chicago, Burlington & Quincy R. R.; iron post stamped "SIDNEY 2687"	2,687.468
Eustis, water tank at railroad station; aluminum tablet stamped "SIDNEY 2624"	2,623.729
T. 8 N., R. 25 W., sec. 3, on Chicago, Burlington & Quincy R. R.; iron post stamped "SIDNEY 2691"	2,691.325
T. 8 N., R. 27 W., southwest corner of sec. 15; iron post stamped "SIDNEY 2767"	2,767.453
T. 8 N., R. 28 W., sec. 2, at ranch house in Curtis Canyon; iron post stamped "SIDNEY 2625"	2,624.743
T. 9 R., R. 28 W., NE. ¼ sec. 25, in Curtis Canyon; iron post stamped "SIDNEY 2678"	2,677.749
Moorefield, in park, 50 feet east and 26 feet south of east end of station, at right angles from center line of main track; iron post stamped "2826 SIDNEY"	2,825.848
Curtis, in park, 50 feet east and 26 feet south of east end of station, at right angles from center line of main track; iron post stamped "2560 SIDNEY"	2,560.071
T. 9 N., R. 28 W., north side of sec. 12, on wagon road down Curtis Canyon; iron post stamped "SIDNEY 2738"	2,738.086
T. 9 N., R. 27 W., sec. 34, on wagon road from Moorefield to Hill's ranch, near township line; iron post stamped "SIDNEY 2851"	2,850.925
T. 9 N., R. 27 W., sec. 15, quarter mile northwest of Hill's ranch; iron post stamped "SIDNEY 2741"	2,740.581

	Feet.
T. 10 N., R. 28 W., NE. ¼ sec. 12, at head of Curtis Canyon; iron post stamped "SIDNEY 2934"	2,934.167
T. 10 N., R. 27 W., SE. ¼ sec. 20, near Beerley's house; iron post stamped "SIDNEY 2850"	2,850.082
T. 10 N., R. 27 W., NE. ¼ sec. 5, on wagon road at head of Conroy Canyon; iron post stamped "SIDNEY 2989"	2,989.333
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T. 11 N., R. 28 W., NE. ¼ sec. 1; iron post stamped "SIDNEY 2769"	2,768.897
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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 474

COALS OF THE STATE OF WASHINGTON

BY

E. EGGLESTON SMITH

WORK DONE IN COOPERATION WITH THE
GEOLOGICAL SURVEY OF WASHINGTON

WASHINGTON

GOVERNMENT PRINTING OFFICE

1911

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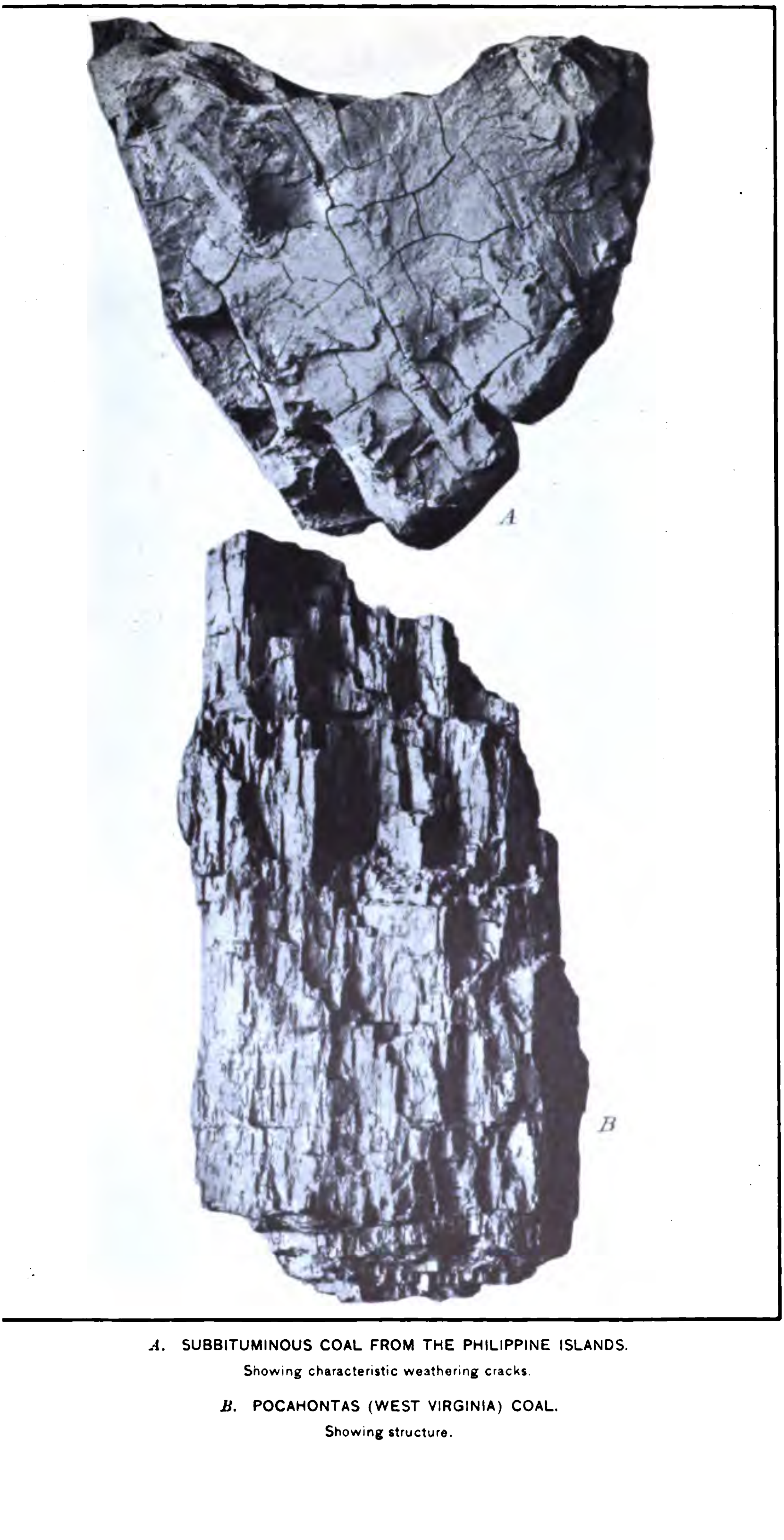

A. SUBBITUMINOUS COAL FROM THE PHILIPPINE ISLANDS.

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Showing structure.

COALS OF THE STATE OF WASHINGTON.

By E. Eggleston Smith.

INTRODUCTION.

The field work on which this report is based was done between the months of June, 1909, and March, 1910. The anthracite coal field at the head of Cowlitz River was examined for the purpose of classifying the coal land in the Rainier National Forest, the work being done entirely by the United States Geological Survey. The remainder of the work was designed to procure as complete data as the funds available would permit concerning the character, quality, and relative values of the coals of the State of Washington, and it was carried on in cooperation with the State Geological Survey. The field work was done under the administrative supervision of Henry Landes, State geologist of Washington, and M. R. Campbell, of the United States Geological Survey.

During the same period a party under the supervision of G. W. Evans, of the Geological Survey of Washington, mapped the surface geology of King County with special reference to coal, and investigated the underground geology as shown in coal mines, the mining conditions and methods, and the preparation of coal for the market. The writer spent parts of July, August, and September, 1909, assisting this party in field work. The results of this investigation will be published by the State.

The writer wishes to express his thanks to all the mine managers, superintendents, and foremen who kindly cooperated with him and assisted in collecting the samples and the geologic and other data used in preparing this report.

EXPLANATION OF TERMS.

In the descriptions of mines and samples in this report certain terms are used which have more or less definite local meanings and as these terms and their meanings may not be familiar to all readers they will be given. The term "water level" is applied to any gangway or drift which has natural drainage above the surface of the surrounding country, or in a general way to the workings lying above a water-level gangway or drift. The lowest water level in a series is spoken of as the first water level, the next above as the second water level, etc. The term "level" is applied to gangways or drifts that lie below the natural drainage of the region and to workings above such gangways, from all of which water must be pumped. They are spoken of in descending order as first level, second level, third level, etc.

The terms "niggerheads," "sulphur" balls, and pyrite nodules are applied to masses of marcasite and pyrite which occur in much of the coal. The term "binder" is applied to any hard, black carbonaceous shale which resembles the coal and which is not easily separated from it either in mining the coal or in preparing it for the market.

In the mines of the Northwestern Improvement Co., in Kittitas County, the block-and-battery system of mining has been installed. The rooms are arranged in groups of ten each. As the gangway advances all the coal from the alternate groups is removed. These alternate groups are called batteries. The remaining groups are worked out as the gangway retreats. These groups are called blocks. The batteries and blocks are numbered independently of each other in consecutive order from the main slope.

For many years the need of a simple, consistent, and satisfactory scheme of classification for coal has been felt by all who have been in any way connected with the coal business, from the geologist and mining engineer to the dealer who places the coal on the market. Recently the United States Geological Survey has adopted a scheme [1] which seems in a way to answer the needs, and new names have been coined and old ones redefined in order to make the schemes suitable for practical use. The groups of coal recognized and the names applied to them are as follows: (1) Anthracite, (2) semianthracite, (3) semibituminous, (4) bituminous, (5) subbituminous, and (6) lignite. The higher grades (anthracite, semianthracite, semibituminous, and bituminous) are generally well known and need little or no description in this report. The type coals of the different groups are easily distinguished, but as there is a complete gradation between the groups the attempt to classify coals that belong in the dividing or debatable ground between the groups is difficult.

The generally accepted criterion for distinguishing the groups from bituminous upward is that of fuel ratio, or the quotient of the fixed carbon divided by the volatile matter, but it is questionable where one group shall end and another start. This question has not yet been settled by the United States Geological Survey and consequently the terms employed in this report will be used as they are used in the trade in the eastern fields of the United States, with the meanings indicated below:

1. Anthracite may be defined as a very hard, jet-black coal having a dense homogeneous texture, a bright irregular conchoidal fracture,

[1] Campbell, M. R., A practical classification for low-grade coals: Econ. Geology, vol. 3, No. 2, March-April, 1908.

burning with a short blue flame, and having a fuel ratio[1] of 10 or more. The coal from the Scranton-Wilkes-Barre district in Pennsylvania is typical anthracite.

2. Semianthracite is below the grade of anthracite, but its limits are not well defined. In general, it is fairly hard and bright, but it resembles bituminous coal in that it is more or less affected by minute jointing. It contains a considerably lower percentage of volatile matter than bituminous coal and has a fuel ratio of about 6 to 10. Coal from the Bernice Basin, Pa., and Spadra, Ark., is representative of this class.

3. Semibituminous coal is the next group below the semianthracite and above the bituminous. This group includes some of the best-known coal of the country, such as the Clearfield coal of Pennslyvania, the Georges Creek coal of Maryland, the New River and Pocahontas (Pl. I, *B*) coals of Virginia and West Virginia, and most of the coal of Arkansas. The fuel ratio of coal of this group ranges approximately from 3 to 6.

4. Bituminous coal includes all so-called "soft coal" which is lower in fuel ratio than semibituminous coal and which does not contain sufficient moisture to cause it to crumble (mechanical breaking down not being considered). In the State of Washington coal from the mines operating at present in Pierce and Kittitas counties and from the Black Diamond and many other mines in King County is typical bituminous coal. The coals of Iowa and Illinois and many of the coals of Ohio, Pennsylvania, West Virginia, Kentucky, and Alabama belong to this class.

5. Subbituminous coal has generally heretofore been called "black lignite." The criteria for the distinction of coal of the subbituminous group are in general (1) grayish black or black color; (2) almost universal absence of a distinct system of joints; (3) high percentage of moisture, which is given off readily on exposure to the sun or air, thus producing the peculiar irregular weathering (see Pl. I, *A*) spoken of as "slacking," and (4) the tendency of many of these coals to separate on weathering into thin plates parallel to the bedding. Of these features the color and the manner of weathering are the most characteristic. The color distinguishes the group from lignite; the manner of weathering separates it from bituminous coal. Fresh blocks of subbituminous coal, when exposed to the air or to the direct rays of the sun, tend to break up independently of the joint planes into smaller and smaller fragments having irregular faces. The fresh coal has a bright luster and an irregular conchoidal fracture; the resultant fragments are lusterless and their surfaces do not show an even fracture of any kind. Certain subbituminous coals have high heating value and will stand transportation in closed cars without

[1] Frazer, Persifor, jr., Classification of coals· Rept. MM, Second Geol. Survey Pennsylvania, 1879, pp. 128-158; Trans. Am. Inst. Min. Eng., vol. 6, 1879, pp. 430-451.

"slacking," but will check slightly when exposed to the direct rays of the sun in open cars. Such coal is evidently near the border line between the bituminous and subbituminous groups. In the State of Washington the coals of Issaquah, Coal Creek, Renton, and Tono are typical of this class.

6. Lignite is distinguished from subbituminous coal by its color, texture, and amount of moisture. It is brown in color or has a distinctly brownish cast. The texture is usually more or less distinctly woody, although some lignite, notably that of Texas, is amorphous. The amount of moisture is greater than that of subbituminous coal and ranges from 25 to nearly 45 per cent. The lignite of North Dakota is typical of this group. The name lignite is perhaps more loosely used at the present time than any other in the list. On the Pacific coast, especially in the State of Washington, this term is applied to all the coals commonly classed as "lignite," "brown lignite," "brown coal," "black lignite," "lignitic coal," and very frequently to a good grade of bituminous coal. The writer has often heard the coals from Black Diamond and Carbonado referred to as lignite, though they are among the best bituminous coals in the State. It is hoped that the classification, with the corresponding nomenclature just given and used throughout this report, will be adopted by the local operators and dealers, for its general features are already in use and it only prescribes, in addition to these features, certain fairly definite limits for the lower groups and introduces the term subbituminous to replace the many terms like "black lignite," "lignitic coal," and "brown coal."

METHODS OF SAMPLING.

COMPARISON OF METHODS.

In attempting to compare the coals of a reigon like the State of Washington, where the character of the coal is so different within short distances and where mining operations are in so widely different stages of development, it is evident that some standard method of sampling must be adopted. Of the three methods commonly employed—sampling at the place of consumption, sampling in carload lots, and sampling from the mine—the last seemed to be the only one that could be used economically under the present conditions of development.

Commercial samples are more nearly representative of the coal as it is placed in the market; but as different methods of preparation for market, varying length of exposure to the air, changing conditions in the different parts of the mine from which the coal is obtained, and other variable factors affect the character of the coal at the consumer's plant, this method of sampling is not very satisfactory, particularly for a low-grade coal.

Carload sampling, if carried on under the supervision of a man skilled in the work and preceded by a careful study of the condition of the bed, the character of the coal in the different parts of the mine, and the method employed for the preparation of the coal for the market, affords a means of obtaining better average results than can be obtained by sampling at the place of consumption. The coal can be so chosen as to be fairly representative of the average output of the whole mine or the sample can be made to represent the average of any particular part of the mine. Much, however, depends on the experience and personal equation of the sampler. This method also permits a choice of shipment, in either open or closed cars, which will place the sample at the laboratory in about the same condition that it would reach the consumer. On the other hand, the great cost of this method of sampling and the responsibility and judgment required of the sampler make it almost prohibitive under ordinary conditions and not so reliable in its general results as mine sampling.

Mine sampling can be applied to all kinds of operating mines, abandoned mines, and prospects in all stages of development to which access can be obtained. In fact, it is the only method that can be employed where the coal is not being used commercially. It costs much less than the shipment and testing of commercial or carload samples and for that reason is much better suited to ordinary requirements. Mine sampling provides a ready means of making a comparison of coal from different places in the same bed—a comparison which can be made by the other two methods only by the expenditure of a large amount of time and money.

Wherever car samples have been taken by the United States Geological Survey, mine samples have been taken at the same time from the working parts of the mine from which the coal came. This practice has been extremely valuable in giving data for comparing the merits of the two methods of sampling and in affording a means of estimating roughly the commercial quality of coals from prospects, developing mines, and other mines, from which carload samples can not be obtained.

Most of the following discussion of the value of coal-mine sampling as compared with carload sampling is taken from an article by M. R. Campbell.[1] In comparing these two methods of sampling the effect on the impurities in the coal is most important, although there is undoubtedly some effect on the other constituents. These impurities, named in the order of their importance, are moisture, ash, and sulphur.

Exposure to the atmosphere has different effects on the moisture in coal, the degree of change depending on the amount of initial moisture, the kind of exposure, and the length of exposure. The

[1] The value of coal-mine sampling: Econ. Geology, vol. 2, No. 1, January-February, 1907, pp. 48-57.

standard method of mine sampling as set forth by Campbell, supplemented by precautions to avoid certain difficulties, should reduce the variation in moisture in mine samples to a minimum. The ordinary method of car sampling is subject to all the conditions producing alteration in the moisture content. The comparison of a large number of mine samples with car samples has made it possible for Campbell to divide into four great groups the coals which have certain relations in their moisture content. The following is Campbell's statement[1] regarding coals tested at the Louisiana Purchase Exposition at St. Louis in 1904:

Group A: This group includes all coals in which the average moisture content of the car sample is less than 3 per cent. Of this group 18 samples show an excess of moisture in the coal from the mines and 6 samples show an excess in the coal from the car. The total excess in the mine samples is 9.47 per cent and in the car samples 5.48 per cent. The difference is 3.99 per cent. This divided by 24, the total number of samples, gives an average excess in the mine sample of 0.17 per cent.

Group B: In this group are included all samples having an average moisture content in the commercial coal of from 3 to 8 per cent. Of this group 18 samples show an excess of moisture in the commercial coal and the other 18 samples show an excess in the coal from the mine. The number of samples is the same in both cases, but the total amounts are quite different, the excess in the car samples being 24.60 and in the mine samples 10.23 per cent. The difference between these amounts, or 14.37, divided by 36, the total number of samples, gives 0.40 per cent as the average excess in the car samples.

Group C: This group includes all samples having a moisture content in the average car sample of from 8 to 10 per cent. Of this group 4 samples show an excess in the commercial coal, and 11 samples an excess in coal from the mine. The total amount of excess in the car samples is 2.24 per cent and in the mine samples 10.69 per cent. The difference, 8.45 per cent, divided by 23, the number of samples, gives an average excess in the mine sample of 0.56 per cent.

Group D: This group includes all samples having a greater amount of moisture in the car sample than 10 per cent. The mine samples show an excess in moisture over the car samples, as in the previous group, but the excuse for considering it separately is that the average amount of excess is much greater than that of the preceding group. Of Group D 8 samples show an excess in coal from the car and 22 samples show an excess in coal direct from the mine. The total excess in the former case is 10.50 per cent and in the latter 48.56 per cent; the difference, 38.06 per cent, divided by 30, the number of samples, gives 1.27 per cent as the average excess in the mine samples.

Tabulated, the results are as follows:

Table of coal groups arranged according to the excess of moisture in mine and car samples.

Groups of coal.	Excess in mine samples.	Excess in car samples.
	Per cent.	*Per cent.*
A. Coals having less than 3 per cent in car samples	0.17	....
B. Coals having from 3 to 8 per cent in car samples	....	0.40
C. Coals having from 8 to 10 per cent in car samples	.56	....
D. Coals having over 10 per cent in car samples	1.27	....

[1] The value of coal-mine sampling: Econ. Geology, vol. 2, No. 1, January-February, 1907, pp. 50-55.

The meaning of the above-described groups is not well understood, especially the reason why an intermediate group, B, should show an excess of moisture in the car samples when coals of both larger and smaller content show less moisture in the car lot than in the mine samples. The reasons for Groups C and D are evident. They include coals having a high moisture content, and it is only reasonable to suppose that coal of this character would lose some of its moisture in transit, especially when the shipment occurred in midsummer, as was the case with most of these samples. It is possible that the coals of Class B were shipped in bad weather and hence gained moisture in transit, or it may be possible that coals of this intermediate grade are in such a condition that they will absorb moisture from the atmosphere more readily than those having either a higher or lower moisture content. It is possible also that Group B is not a natural group, but merely due to fortuitous circumstances. If that is the case, a larger series of tests would probably show that no such group exists.

The effect of the two methods on the amount of sulphur in the sample is slight. The following report is Campbell's statement [1] on this point:

Of the 105 samples analyzed during the two years, 75 show an excess of sulphur in the commercial coal, 28 show an excess in coal direct from the mines, and 2 show an equal amount in each. The total excess in car samples is 261.67 per cent, and in mine samples 246.25 per cent; 261.67 divided by 246.25 equals 1.06, the coefficient of excess of sulphur in the car samples over the mine samples. If, therefore, the amount of sulphur shown in any analysis of coal direct from the mines be multiplied by 1.06, the result will be approximately the amount of sulphur that may be expected in commercial coal from the same mines.

The amount of ash in the samples obtained by the two methods depends on the personal equation of the mine sampler and the car sampler, on the character of the roof and floor of the mine, on the methods of mining and hauling to the surface, and on the methods of preparation for market if the sample is taken after it has been cleaned. The results of the comparison of the ash as given by Campbell [2] are as follows:

The total excess in the car samples is 1,062.66 and in the mine samples 825.95 per cent; 1,062.66 divided by 825.95 equals 1.29. This may be called the coefficient of increase, and can be used in converting the ash in analyses of mine samples into analyses of commercial coal; thus, if the ash in the analysis of the mine sample be multiplied by the coefficient, 1.29, the result will be approximately the amount of ash that may be expected in commercial coal from the same mine.

The percentage of volatile combustible matter in a coal undoubtedly changes on exposure to the air, and the amount of change depends on the length of exposure, the size of the particles, and the amount of weathering. It has been shown by R. T. Chamberlin [3] that fresh coal dust gives nearly four times as much volatile combustible as old dust. The rate of change is undoubtedly controlled by the size of the particles and the amount of air in circulation among them.

[1] The value of coal-mine sampling: Econ. Geology, vol. 2, No. 1, January-February, 1907, p. 52.

[2] Idem, p. 53.

[3] Notes on explosive mine gases and dusts: Bull. U. S. Geol. Survey No. 383, 1909, p. 62.

The following conclusions may be drawn concerning the comparison of the standard methods of mine sampling and car sampling. First, no exact ratio can be established between the amounts of moisture in the two kinds of samples, because of the varying conditions of original moisture content, methods of transportation, and time of transportation. Second, a more or less definite ratio exists between the amount of sulphur in the two kinds of samples, which may be used as a possible basis for estimating the amount of sulphur in commercial coal from the analysis of a mine sample, although the variation of many of the samples from this ratio is great. Third, a more or less definite ratio exists between the amounts of ash in the samples, which may be used with considerable accuracy in determining from the mine sample the possible ash in a commercial sample.

METHODS USED.

In collecting samples from mines operating on one bed the writer took one sample from each mine having a daily output of 200 tons or less. An additional sample was taken for each additional 100 tons of output; that is, a mine producing 500 tons daily would have one sample for the first 200 tons and three samples for the additional 300 tons, or a total of four samples.

The following method was used in collecting such samples. After ascertaining the parts of the mine at which the coal bed was most nearly normal, points were selected for sampling in the center and the periphery of the active workings which would give samples representing very closely the present and the future output of the mine. At the place where each sample was taken a fresh face of coal was selected and cleaned of all coal dust, powder stains, and other impurities by removing from half an inch to 2 inches of the coal. In slightly dipping beds, where the floor of the mine was wet, a piece of oilcloth was spread so as to catch the coal as it was cut and to keep out impurities and moisture. In highly dipping beds the oilcloth was supplemented by a small canvas bag on a hooped stick which could be held immediately under the part of the bed being sampled and which caught most of the coal as it was cut from the face. The sample was obtained by cutting a channel across the face as nearly perpendicular to the floor as possible and of such a size as to yield about 5 pounds of coal to each foot of the bed sample. All material in the bed was included except partings, lenses, and binders more than three-eighths of an inch thick and lenses or concretions of "sulphur" or other impurities greater than 2 inches in maximum diameter and half an inch in thickness. In some places a layer of the foreign material resembled the surrounding coal so closely that it could not be separated in preparation for market and was therefore included in the sample. Some beds also contained thin partings which could not be entirely separated from the coal by picking and washing. Several of these partings were also included in the sample, so that the amount of ash would be about the same as that contained in the commercial coal that had been carefully prepared for the market. In the sections of the beds which are given with the descriptions of the mines (see pp. 77–199) an asterisk (*) or dagger (†) indicates the parts which are included in the sample. Only half of some layers was included, and such layers are indicated by a dagger. Some samples were wet when they were taken from the mine. As most of the sampling was done in the winter or rainy season, it was not possible to dry all samples before being ground and sealed in the can. When the weather was so dry that the sample could be dried without being exposed to the air very long, it was air-dried until all visible moisture had disappeared before it was prepared for the laboratory.

The samples of washed coal, lump coal, and steam coal were taken from the surface of the storage bins and from the surface of railroad cars which had just been loaded. The coal was collected in small quantities at more or less regular intervals until 75 to 300 pounds was obtained.

PREPARATION OF SAMPLE FOR THE LABORATORY.

The mine sample was prepared for the laboratory either in the mine or in a protected place at the entrance to the mine where the atmospheric conditions were similar to those of the mine. Each sample was kept in an oilcloth bag until the sampler was ready to pulverize it. The coal was ground in a bone grinder to the size of a pea, or pulverized with a piece of flat steel and an iron pestle until it would pass through a sieve with a half-inch mesh. It was then thoroughly mixed and quartered. Opposite quarters were rejected, and the remaining quarters were thoroughly mixed and quartered as before. The operations of mixing and quartering were repeated until the final sample of about one quart was obtained. This was then placed in a screw-top galvanized-iron can made to hold about 3½ pounds of coal, and was sealed and mailed to the Geological Survey's laboratory at Pittsburg for analysis.

The samples of washed coal, lump coal, and steam coal were thoroughly mixed. The pieces were then reduced to a diameter of three-fourths of an inch and mixed and quartered in the usual way until a sample of about 25 pounds was obtained. This was ground in a bone grinder to the size of a pea and then mixed and quartered until a final sample of about 3½ pounds was obtained, which was sealed in a screw-top galvanized-iron can and sent to the laboratory.

If the exact location of the place from which a sample was taken is not known, its location with respect to a known land corner is given in the description of the individual mines and prospects, so that its position can be readily determined. Mine maps were not available to determine some locations, and their exact position with regard to a Government land corner is not known. For such places the location of the mine is given as nearly as possible by distance and direction from the nearest town.

CHARACTER AND QUALITY OF THE COAL.

INTRODUCTION.

The character and quality of the coals of the State were ascertained by determining their chemical composition, calorific value, physical properties, and impurities. The relative heating and commercial values of coal depends largely on the character, relation, and proportion of its chemical constituents. Its ability to stand transportation, and hence to a considerable degree its commercial value, depends largely on its physical properties. Its relative heating value and its adaptability to special uses is strongly influenced by the impurities it contains, so that a knowledge of the character and amount of these impurities is all-important in determining the commercial value of the coal.

CHEMICAL PROPERTIES.

METHODS OF ANALYSIS.[1]

Two kinds of analyses were made at the Survey's laboratory—the proximate analysis and the ultimate analysis. A proximate analysis determines by a conventionally standardized process the coal's percentage of moisture, volatile matter, fixed carbon, ash, and sulphur. An ultimate analysis determines the ultimate constituents—hydrogen, carbon, nitrogen, oxygen, sulphur, and ash. Calorific determinations were made when called for, and the heating value is expressed in both calories and British thermal units, the calorie being 1.8 times the British thermal unit. In mines that are working on the same bed it was customary to take the ordinary number of samples from each mine and make only a proximate analysis of each. If these analyses showed no considerable variation in the composition of the coal an ultimate analysis and a calorimeter determination were made of a composite sample consisting of equal amounts from each of the original samples. If the analyses showed marked differences in composition, ultimate analyses and calorific determinations were made of the samples showing the variations and a composite sample was made of the remaining samples. Various conditions determined whether a proximate or an ultimate analysis should be made of a particular sample. Generally speaking, a

[1] For a full discussion of the methods of analysis used at the Government laboratory see Prof. Paper U. S. Geol. Survey No. 48, 1906, pt. 1, pp. 174-195. Also Lord's paper on air-drying.

proximate analysis was made of a coal that was weathered or altered by volcanic action or that was believed to be high in ash, but an ultimate analysis was made of a coal that was not weathered or altered and was believed to be a good commercial coal. Ash determinations were made on samples which were believed to contain so much ash that it was doubtful whether or not the coal they represented had any economic value.

A large number of mine samples and many samples of washed and prepared coal contained much more moisture than was inherent in the coal. In order to compare the heating value of the coal from a wet part of a mine with that from a dry part, or with that from a dry mine, or the coal from a washer with dry coal from the mine, some system of drying the samples to a uniform condition must be adopted. By continued experiment it was found that proper comparisons can be made by weighing the coal in a shallow galvanized iron tray and drying it in an oven through which a gentle current of air heated from 10° to 20° above the temperature of the laboratory is passing until the weight becomes practically constant. The difference in weight between the original sample and the partly dried sample gives the amount of moisture driven off by air drying. This process is not intended to produce the same effect as the exposure of the coal to the air and sun during transportation. It simply appears to be the best method of determining roughly the amount of moisture loosely held by the coal.

In actual practice analysis is made of the air-dried sample. The figures given opposite the items "As received," "Dry coal," and "Pure coal" are calculated from the analysis of the air-dried sample and are included in the table for convenience in comparing and studying the analyses. The figures opposite "Dry coal" represent the analysis calculated for the coal when free from moisture; those opposite "Pure coal" represent the analysis calculated for the coal when free from moisture and ash. The term "pure coal" is somewhat misleading as the coal so designated includes sulphur, but the term is used simply on account of its brevity and convenience.

ANALYSES OF THE COALS.

Analyses of samples of coal collected by the writer in Washington were made at the laboratory of the United States Geological Survey at Pittsburg, and the results are given in the table on pages 41–75. Samples 6760 and 6761 were taken by J. S. Diller[1] in Cowlitz County in 1904. These were analyzed by W. T. Schaller in the laboratory of the United States Geological Survey at Washington, D. C. In

[1] Diller, J. S., Coal in Washington near Portland, Oreg.: Bull. U. S. Geol. Survey No. 260, 1905, pp. 411–412.

1905 M. R. Campbell[1] collected mine and carload samples from the Renton mine, in King County (Nos. 2455, 2456, 2686, 2687), and the Roslyn mines, in Kittitas County (Nos. 2457, 2458, 3098). Two mine samples (Nos. 2459 and 2460) were collected by M. R. Campbell at about the same time from the Carbon Hill mine at Carbonado, the results of which have not been published but which compare favorably with the analyses of samples collected by the writer from the same mines and from the same beds. Sample 6487 was collected in 1908 by J. B. Umpleby from the No. 5 bed at Ravensdale. Samples 6486, 6488, 6489, 6490, 6491, 6492, 6493, 6494, 6495, and 6496 were collected by J. B. Umpleby at the same time from prospects and mines in Lewis and Pierce counties. Samples 520–D and 6485 were collected from Taylor and samples 552–D, 787–D were obtained by K. M. Way from Carbonade. These samples, together with those collected by Umpleby, were analyzed at Pittsburg, Pa., and the results are given in the accompanying table. Samples 11736, 11737, and 11738 were collected by George W. Evans after the completion of the author's field work from mines that were not then in operation. Samples of coal from Whatcom and Skagit counties were analyzed by the Bureau of Naval Equipment,[2] Washington, D. C., and are given in the table on page 76 to afford a comparison of these coals with the other coals of the State.

In the table the locations of the samples are given by township, range, section, and quarter section. On account of the absence of accurate maps the locations by section or quarter section of some of the prospects sampled may be incorrect, but they are as near as could be determined with the means at hand and the knowledge of the legal subdivisions. Under the column headed "Thickness" the total bed as sampled, including the partings, is given under the heading "Coal bed." Coal which was either not exposed or of no commercial value, underlying or overlying the part sampled, is not included in the thickness given. This thickness minus the thickness of all the partings not included in the sample is given in the column headed "Part sampled."

The general opinion of the members of the laboratory staff is that the methods used for determining the values given in the proximate analysis are not sufficiently refined to warrant the use of the second decimal place in recording the results. Therefore those percentages which are not directly involved in the ultimate analysis are given to the nearest tenth. In like manner it is believed that the methods used in the determination of calorific values are not accurate enough

[1] Report of the United States fuel-testing plant at St. Louis, Mo.: Bull. U. S. Geol. Survey No. 332, 1908, pp. 272–277.

[2] Reports of the efficiency of various coals, 1896 to 1898, and expenses of equipment abroad, 1902–3, and recent chemical analyses of coal at the navy yard, Washington, D. C., 1906, pp. 5–7, 96–99, 119–121.

to justify the use of unit value and hence the amounts of calories are given to the nearest five and British thermal units are given to the nearest ten.

EFFECT OF DIFFERENT CONSTITUENTS OF COAL.

In the table under proximate analysis four constituents of the coal are given and under ultimate analysis five, with ash common to both. They are as follows: (1) Moisture, (2) volatile matter, (3) fixed carbon, (4) ash, (5) sulphur, (6) hydrogen, (7) oxygen, (8) nitrogen, and (9) carbon. The influence of each constituent is in general as follows:

The moisture in a sample of coal consists of (1) extraneous moisture, which occurs on the surface of the different particles or grains and which is the result of seepage from adjoining rocks, water from washing of the coal for market, precipitation on the coal when exposed to the open air, or sweating, which is a precipitation of moisture from warm saturated air coming in contact with relatively cooler coal; (2) moisture inherent in the coal—that is, residual water from the original organic matter, or water evolved by chemical change. Moisture is the constituent which has the greatest effect in reducing the heating value of the lower grades of coal. This reduction is due to the fact that moisture is inert and does not produce heat, and that it absorbs heat from the coal during its rise in temperature to the evaporation point and during its conversion into steam. It is evident also that for each unit or per cent of moisture contained in the coal there is one unit or 1 per cent less of combustible matter which might have been there if the moisture were absent. By considering this fact alone it becomes evident that each per cent of moisture decreases the efficiency of the coal 1 per cent or 20 pounds per ton. In addition to this it should be noted that the amount of heat required to raise the temperature of the water from the normal to the boiling point and then to convert it into steam is 620 calories of heat for each kilogram of water, or 282 calories per pound, which is equivalent to about 0.035 per cent of the heating value of a ton of pure coal for every per cent of moisture in the coal. In high grade coal the loss due to moisture is very small, but in low grade coal it is an important quantity. Other conditions being equal, coal containing 40 per cent of moisture will have about 41.4 per cent less heating value than one which is absolutely free from moisture. A relatively small percentage of moisture does not materially affect the adaptability of coal for many uses, but a large amount, such as that contained in subbituminous coal and lignite, causes the coal when placed upon a hot fire to swell and crumble to pieces, so that it can not be used with forced draft without great loss of fuel and great danger from fires from the hot cinders thrown out of the smokestack.

The volatile matter[1] of a coal consists of two parts—(1) combustible and (2) noncombustible. That part of the volatile matter which unites with oxygen and produces heat is composed chiefly of hydrocarbons, sulphur, and hydrogen.[2] The hydrocarbons have a heat of combustion ranging from about 1.3 to 4 times that of carbon, and therefore increase the efficiency of the coal. Other things being equal, the greater the percentage of combustible volatile matter in a coal the higher its heating value. The effect of the percentage of hydrocarbon on the heating value of coal is shown by the well-known fact that anthracite coal, which contains a relatively small amount of volatile combustible matter, has a markedly lower heating value than semibituminous coal (Pocahontas, New River, etc.), which contains a much higher percentage of volatile combustible matter.

In the coals of Washington sulphur usually occurs in small quantities, ranging from a fraction of 1 per cent to 3 per cent. When free it has a heating value much less than that of carbon, and would therefore tend to lower the efficiency of the coal. Free hydrogen has a heating value more than four times as great as that of carbon. The presence of this gas in the coal would raise its calorific value.

That part of the volatile matter which does not produce heat and which is regarded as "inert" consists of oxygen and nitrogen. The effect of these gases is to reduce the heating value of the coal, the principal effect of the oxygen being, according to Du Long's formula, to reduce the hydrogen available for heat by so much as is necessary to form water with the oxygen present $(H-\frac{O}{8})$. Nitrogen is believed to have generally no effect other than to decrease in proportion to its amount the percentage of combustible matter in the coal, and therefore to decrease the total heating value. Oxygen in excess of the amount which may unite with hydrogen to form water reduces the heating value because it replaces an equal amount of combustible matter. (See p. 21.)

Carbon is the principal combustible in most coal. Other things being equal, the higher the amount of fixed carbon the higher the heating value of the coal up to a certain limit. Carbon has not, however, so high a heating value as hydrocarbons, and therefore some coals which have a relatively large amount of hydrocarbons have a higher efficiency than those which have a large amount of carbon. This appears to be true only of coals having a small amount only of incombustible volatile matter. Those containing less than 55 per cent of fixed carbon generally have a lower heating value, due to

[1] For discussion of the volatile matter in coal see the report of S. W. Parr, Bull. Illinois State Geol. Survey No. 3, 1906, pp. 31-49.

[2] The occurrence of free hydrogen in coals is believed to be very rare. R. T. Chamberlin (notes on explosive mine gases and dusts, Bull. U. S. Geol. Survey No. 383, 1909, p. 31) reports the finding of a small amount of free hydrogen in a gas issuing from a standpipe for anthracite coal near Wilkes Barre, Pa.

larger quantities of other volatile constituents, principally moisture or oxygen, otherwise combined in the coal.

Ash is one of the important factors that determine the heating value of the coal. It is generally inert and does not produce or absorb heat, so that in this respect its effect is negative. Each per cent of ash in the coal not only replaces 20 pounds per ton of combustible matter, but means just 20 more pounds of useless material to be handled, and if the ash is fusible it acts as a positive detriment to the coal.

The constituents of coal shown in an ultimate analysis have a more or less definite significance as to its heating value. As stated above, sulphur tends to decrease the calorific value of the coal, but if it exists as free sulphur it has a small heating value. The amount of available hydrogen above the ratio needed to satisfy the oxygen in the formation of water increases the heating value. The effect of oxygen, as already stated, is to reduce the heating value. David White[1] states that its effect in reducing the heating value is about the same as that of ash and that oxygen and ash are of nearly equal anti-calorific importance. Nitrogen is inert and as a diluent reduces the heating value in proportion to its amount. Carbon has a heat of combustion about equal to that of pure anthracite and when not in combination with oxygen is the principal heat-producing element of coal.

EASE OF IGNITION.

Many of the coals of the State of Washington ignite much more easily than coal from the eastern part of the United States. A splinter from almost any of the purer Washington coals can be burned readily with a match, but the flame produced is usually not self-sustaining. The coking coal of Pierce County swells and sputters in the flame and shoots out burning gases in the form of little jets. Coal samples from Black Diamond, Ravensdale, and Roslyn burn with a long flame while a match is burning under them, but the flame dies out very soon after the match is removed. The subbituminous coals can be burned, but not so readily as the other coals. The coal from Fuca, Clallam County, is easily ignited, and the flame is self-sustaining in still air. The low-grade coal from Chehalis will give off a very dense smoke, but will not burn independent of the match. The cannel-like coal which occurs in pockets in the Mendota mine burns very readily and the flame is self-sustaining. This coal gives a much larger flame and more soot than any other cannel coal with which the writer is familiar.

In general, those coals which have the larger percentage of volatile matter in the analysis of the moisture-free sample ignite the more

[1] The effect of oxygen in coal: Bull. U. S. Geol. Survey No. 382, 1909, p. 8.

readily. A small fragment of a coal containing about the same proportion of volatile matter as fixed carbon will sustain a flame after it has been ignited by the flame of a match. The coal from Clallam County has nearly 10 per cent more volatile matter than fixed carbon. The coal from Mendota, already referred to, is believed to have a still higher proportion of volatile matter. This appears to be the reason why these coals burn so readily. The coal occurring near Chehalis has much more volatile matter than fixed carbon, but the percentage of moisture is high, and this fact probably accounts for the difficulty encountered in igniting the gases from the coal. If the moisture could be driven off, the resulting coal would probably burn easily when ignited by a match.

PHYSICAL PROPERTIES OF THE COALS.

RESULTS OF PHYSICAL TESTS ON COALS SAMPLED.

The coal of the different groups has certain physical properties which, taken collectively, serve as a practical basis of considerable value for determining the character of the coal. The more important of these properties are as follows:[1] (*a*) Color: (1) of the coal, (2) of the streak, and (3) of the powder; (*b*) luster; (*c*) structure: (1) beds and (2) joints; (*d*) texture; (*e*) fracture; (*f*) coherence; (*g*) adherence of powder; (*h*) flexibility; (*i*) elasticity; (*j*) hardness; (*k*) impact; (*l*) specific gravity, and (*m*) mineral accessories. To these properties may be added those which result from combustion—kind of flame, odor of smoke, and character of ash. Tests for most of these physical properties were made by the writer on about 100 samples during the field season and on about 20 other samples while in the office.

The color of the coal ranges from pitch black to brownish black. Anthracite coal and the best grade of bituminous coal are pitch black. Impure bituminous coal, or bituminous coal with which a large amount of ash is intimately mixed, and subbituminous coals are grayish black, although fresh fractures of high-grade subbituminous coal are pitch black. Lignite has a distinctly brownish tinge. Coal from the vicinity of Centralia and Chehalis has only a faint touch of brown, and the classification of this coal is doubtful because it is very near the boundary line between low-grade subbituminous coal and high-grade lignite. No true brown lignite was observed by the writer.

The color of the streak on unglazed porcelain varies from black through dark brown and reddish brown to a light brown which is nearly yellow, and its relative blackness appears to indicate approximately the comparative value of the coal. Anthracite and the highest grade of bituminous coal have a black streak. Bituminous coal has

[1] This list of physical properties is taken from a table made by a committee of geologists of the United States Geological Survey after extended experimentation with coal from all parts of the United States. The table is issued in pamphlet form for the field use of the members of the Federal Survey.

a dark-brown streak—the darker the streak the better the coal. Subbituminous coal and high-grade lignite have a reddish-brown streak; the darker color is characteristic of subbituminous coal and the lighter color of high-grade lignite. The change of the reddish-brown streak from dark to light is approximately in proportion to the decrease in heating value and the increase in the moisture content of the coal. The only light-brown streak is given by the cannel-like coal which occurs in pockets and lenses in the low-grade subbituminous coal near Centralia. The streak of this coal is nearly yellow. In general a large amount of ash intimately mixed with coal will produce a lighter streak than that given by a sample of the same grade of coal which does not contain so much ash. The difference of intensity of color of the streak of bituminous coal in different parts of the same bed is possibly due to the presence of ash in varying proportions.

The color of the powder ranges from black to reddish brown. With the powder as with the streaks, the degree of blackness seems to indicate approximately the quality of the coal, and the same general range of color applies to about the same classes of coal, except that the color of the powder is never so intense as that of the streak. Ash affects the color of the powder of bituminous coal much as it affects the color of the streak.

The difference in luster does not seem to follow closely the change in quality of the coals, although it serves to distinguish certain classes. With few exceptions anthracite and high-grade coking coals have a vitreous luster. Low-grade bituminous coal or coals having a high ash content have a vitreous luster not nearly so bright as that of the better grades. Subbituminous coal may have a slightly vitreous luster when freshly fractured, but it becomes dull on weathering. Coal from the vicinity of Centralia and Chehalis, when freshly fractured, has a dull, slightly satiny luster, which becomes dull and earthy in a short time. The luster of a fresh surface resembles that of impure cannel coal.

The bedding does not vary with the character of the coal. The anthracite and bituminous coals of the State have a bedded and banded structure. Some of the bituminous coals have a foliated structure, but this foliation occurs only in regions of extreme folding. In many places, notably near Centralia and Chehalis, subbituminous coal has massive structure.

The joints of the coal of the different groups are similar within the group. In the anthracite beds only the major joints are visible. The coal is considerably crushed in places and has irregular diagonal slips. The joints of the coking coal are very prominently developed, and the minor joints are so prominent that it is difficult to distinguish a system of major joints except where they pass through bony layers or extend into the roof or floor. In many places the coal is so badly broken that it can be easily crushed in the hand. The noncoking bituminous coal has well-developed major joints. The face cleats (joints), which frequently extend into the roof and floor, are usually either in the direction of the dip or at a small angle from it, and the butt cleats are nearly at right angles to the face cleats. The development of the major joints is more prominent in coal low in intrinsic ash—that is, ash intimately mixed with the coal—than in bony coal. The major joints range from an inch to about 2 feet apart. These are much more prominent in the purer coals, and they are scarcely developed at all in the very bony coals. The subbituminous coal is generally broken by major joints, but the joints are much farther apart than in bituminous coal having the same percentage of intrinsic ash. The face joints are the more perfectly developed and usually occur from 6 inches to a foot apart. The butt joints are generally very poorly developed, as are also the minor joints in the few places where they are present. The low-grade coal near Centralia and Chehalis has a system of major joints, in places well developed, corresponding approximately to the dip. The joints are usually a foot or more apart, but may be found only an inch or two apart. The butt joints are scarcely noticeable, so that the coal breaks with a splintery end between the face joints. So far as the writer observed, minor joints are absent.

The texture of the coal appears to change with the ash content, and the differences are probably due to the manner of the original deposition of the coal. Pure anthracite has a dense texture. Bony coal associated with anthracite consists of layers of pure coal and of bony shale which give the whole a laminated texture. Good coking coal is so minutely jointed that it is difficult to determine the texture, and noncoking bituminous coal is laminated in proportion to the amount of intrinsic ash. Subbituminous coal is generally laminated, although in places the lower grades show a woody texture. The texture of the coal in the vicinity of Centralia and Chehalis appears, at a casual glance, to be almost earthy, but close examination shows it to be slightly woody.

The fracture varies considerably, but is generally uniform in the same group. It appears to vary with the hardness, the amount of ash, and the amount of moisture. Anthracite has an irregular conchoidal fracture with very bright faces and sharp edges, which becomes splintery where there are bony layers. Bituminous coking coal has a cubical fracture, which is somewhat hackly where the joints are oblique. Bituminous noncoking coals have an irregular fracture which becomes progressively more splintery as the amount of intrinsic ash present in the coal increases. Subbituminous coals exhibit irregular conchoidal fracture, the amount of irregularity being about in inverse proportion to the amount of moisture. The fracture of the coal near Chehalis and Centralia is somewhat conchoidal, but mostly splintery. This coal resembles cannel coal in physical appearance and this similarity probably explains the character of the fracture.

The coherence of the coal varies with the amount of ash and the degree of devolatilization or metamorphism. Coals high in ash are generally tough. Coals low in ash which have been altered to a good grade of bituminous or anthracite are generally brittle. Bituminous coking coal is as a rule very crumbly. Coal low in ash and high in moisture is generally, but not invariably, tough.

As explained on page 31, the adhesive power of the powder is in direct proportion to the coking quality of the coal. Anthracite coal does not adhere at all. The adhesive power of bituminous coking coal ranges from medium to good. Many bituminous coals show slight coking tendencies, and their powder adheres slightly, but they will not produce commercial coke. The other bituminous coals and the subbituminous coal give powders which do not adhere, but which pack to a greater or less degree between the mortar and the pestle.

The elasticity of coal appears to depend both on its hardness and on the amount of moisture it contains. Anthracite is fairly elastic. Medium-grade bituminous coal, notably that from Roslyn and the vicinity of Black Diamond and Bayne, is very elastic. The pick, if not properly sharpened and squared, will often rebound from a face of these coals without cutting at all, and sometimes the strength of the recoil is very noticeable. High-grade bituminous coal which is finely jointed does not show elasticity because of the closeness of the joints and the distribution of the force of impact they effect. The elasticity of subbituminous coal and lignite probably increases with the amount of moisture.

The hardness of the coal appears to vary directly with the amount of devolatilization or metamorphism, and inversely with the moisture content. As a rule the higher the percentage of fixed carbon and the lower the percentage of ash the harder is the coal; a notable exception among the Washington coals is that of the Fuca mine, Clallam County. This coal is somewhat high in moisture and very low in fixed carbon, which is only 90 per cent of the amount of volatile matter, but fresh samples compare favorably in hardness with the best grade of bituminous coal in the State.

The character of the impact depends on the hardness and the jointing of the coal. In general, the harder the coal the more metallic will be the impact, and the softer the coal and the more frequent the joints the duller will be the impact.

The specific gravity of the coal depends on the amount and kind of ash, the absence of moisture, the extent of devolatilization, and consequently on the percentage of fixed carbon. Anthracite has a specific gravity at least 10 per cent greater than bituminous coal, and bituminous coal a somewhat higher specific gravity than subbituminous coal and lignite. The bituminous coals of the State which are high in ash have a high specific gravity, as is shown by the greater specific gravity of the bony layers that are separated from the purer coal by washing. Coal containing a large amount of moisture is low in specific gravity, because the moisture, which forms a definite part of the mass, has a lower specific gravity than the average of the other constituents of coal which it replaces.

The mineral accessories vary considerably, but none except resin indicate the character of the coal. Resin was not found in the State by the writer except in coal that is only slightly altered from its original state of deposition, such as the low-grade subbituminous coal of Thurston, Lewis, and Cowlitz counties, and to some extent the high-grade subbituminous coal of Lewis, Thurston, and King counties. Sulphur is found in coal of all kinds, from lignite to anthracite; the largest amount is found in the Fuca coal, which in the sample analyzed contains 5.97 per cent. In this bed the sulphur is disseminated through the coal, or occurs as thin lenses of marcasite or pyrite and as "nigger-heads" in places several feet in maximum diameter. In the other coals the sulphur usually occurs in "sulphur" balls and "nigger-heads" of varying sizes. The presence of mineral charcoal in the beds was not observed.

The character of the flame depends on the amount and character of the volatile combustible. Anthracite, which has a low percentage of volatile combustible, burns with a short blue flame, and oxidation of the combustible matter is practically complete. As a rule the bituminous coal of the State has a high percentage of volatile combustible. It burns with a long yellow flame and produces a large amount of smoke in an ordinary furnace. Under forced draft it produces a very high temperature in the uptake. Subbituminous coal and lignite also have a large percentage of volatile combustible and burn with a long yellow flame and the accompanying large amount of soot and smoke.

The odor of the gases resulting from the combustion of anthracite coal is mostly sulphurous. The prominence of this odor is probably due to the relatively small percentage of hydrocarbons in the coal. The odor of gases from bituminous and subbituminous coals is bituminous and is due to their large content of hydrocarbons, although sulphur frequently occurs in sufficient quantities to be distinctly noticeable. Lignite gives out, in combustion, an odor between bituminous and resinous.

The character and amount of ash depend on the amount of the original ash of the vegetable matter and on the amount of extraneous mineral matter represented by such impurities as partings, lenses, "sulphur" balls, and roof and floor rock, which can not be readily separated in mining the coal and preparing it for market. Except in a very few of the high-grade bituminous coals and the low-grade coal in the vicinity of Chehalis, the amount of ash is generally medium or high. Coals having a white ash contain only a small amount of iron; a red ash indicates the presence of a larger quantity. The tendency of coal to clinker is believed to be due to the fusibility of the iron in the ash. Inasmuch as the use of coal for some purposes depends to a considerable extent on freedom from clinkers, coal having a white or light-colored ash is preferable to coal forming darker ashes. The fineness or coarseness of the ash depends to a considerable extent on the amount of intrinsic ash of the coal; those coals which have a low percentage of such ash burn completely, leaving a powder, and those which have a high percentage do not burn completely, but leave what is called a "core."

SUMMARY.

Anthracite coal has the following characteristic physical properties: Black color, streak, and powder; pitch black, brilliant luster; massive or bedded structure with only major joints; dense texture; irregular conchoidal fracture with very bright faces and sharp edges; considerable elasticity; very hard, distinct, metallic ring on impact; high specific gravity; short blue flame with relatively little odor and no smoke on combustion.

Bituminous coal has the following characteristics: Black color and dark-brown streak and powder; bright vitreous or dull luster; structure generally banded by layers of slightly different character and more or less broken by joints; texture locally dense, but usually banded in proportion to the amount of intimately mixed ash; fracture varying from cubic through hackly and irregular to splintery; adherence of powder proportional to the coking quality of the coal; elasticity depending on the purity of the coal and the absence of joints; hardness variable but generally intermediate between that of anthracite and that of subbituminous coal; impact dependent on joints and less metallic than that of anthracite; specific gravity somewhat less than that of anthracite and greater than that of subbituminous coal; long flame and considerable smoke, with a distinctly bituminous odor on combustion.

Subbituminous coal exhibits the following characteristic physical properties: Black color, with a reddish-brown streak and powder; massive structure, in places slightly bedded and generally free from minor joints; laminated, woody, or earthy texture; fracture generally conchoidal, but in some varieties cubical; adherence of powder very slight; considerable elasticity; hardness in inverse ratio to the moisture content; dull impact; low specific gravity; occasional occurrence of resin: long yellow, smoky, resinous or bituminous flame on combu and "slacking" on exposure to the air through loss of moisture. In point of coherences the coal is generally tough, but it may occasionally be brittle.

Lignite has the following physical properties: Brown color, with reddish-brown streak and powder; dull, woody, or earthy luster, in places slightly satiny, resembling cannel, when freshly fractured; massive structure between partings; structure having only large joints; fracture generally conchoidal, but locally splintery, resembling cannel; coherence usually tough; no adherence of powder; elasticity noticeably high; dull impact; low specific gravity; frequent occurrence of resin; long yellow, very sooty and smoky flame on combustion.

EFFECT OF EXPOSURE ON MOISTURE.

Coal high in moisture gives up a small percentage of moisture on exposure to the air when not kept continually wet by precipitation or by artificial means. It is also believed that subbituminous coal and lignite, which have a very large percentage of moisture, give up a much larger amount if exposed immediately to dry air or the sun than they do after standing for some time exposed to mine air or moist air or after weathering when not exposed to excessive drying.

Two samples (Nos. 9089 and 9573) from the upper bench of the Hannaford mine at Tono were collected from the same face. Sample No. 9089 was perfectly fresh. It was obtained when the top coal was being drawn in a room of the lower bench. The can containing the sample was broken, however, in transit, exposing for only a few hours the sample to the atmosphere of a small mail sack which was not exposed to the sun. The coal was then transferred to a new can and sealed air tight. The work in this room of the mine was abandoned soon after the writer's visit. Nine weeks later a second visit was made to the mine to obtain another sample. The original channel from which the first sample was obtained was found intact. Two inches of the coal to the right of the channel was removed, after which the second sample (No. 9573) was cut by channeling across this face in the same manner as before. This sample was exposed to the mine air about nine weeks and was, therefore, presumably slightly weathered. The total moisture content, however, of the two samples was nearly the same, and is about the same as in other samples obtained in this mine. This indicates that very little moisture evaporated from the coal during its exposure to the mine atmosphere. A computation from the moisture content of the two samples shows that 23.8 per cent of the total moisture of the first sample (No. 9089) was retained after air drying, as compared with 66.5 per cent of the second sample (No. 9573). In the other samples the amount of moisture retained was as follows: No. 9095, 26.3 per cent; No. 9094, 24.3 per cent; No. 9096, 26.4 per cent. The average of the three is

25.7 per cent. In July two cars of run-of-mine coal from the lower bench were shipped from the mine to Pittsburg, Pa., and the analysis (No. 8752) of the coal as it reached the laboratory is given in the accompanying table (p. 75). This analysis shows that 71.9 per cent of the total moisture which reached the laboratory was retained on air drying, or 58.7 per cent of the total moisture which left the mine, which is about 2½ times the average held by the mine samples.

M. R. Campbell referred the writer to a similar change which took place in a car sample of North Dakota lignite collected by him in 1905 and tested at the fuel-testing plant of the United States Geological Survey at St. Louis, Mo.[1] In two mine samples, No. 1971 retained 15.4 per cent of the total moisture on air drying and No. 1972 retained 20.8 per cent. A car sample contained 68.1 per cent of its total moisture after air drying, or about 47.3 per cent of the total moisture it contained before drying in transit and storage. Campbell reports that the coal was shipped in a closed car from the mine to St. Louis, but that all the storage bins were full when it arrived at the laboratory and the sample was dumped in a pile in the open air. It had stood exposed to the air for some time when it was finally analyzed and tested.

The effect of exposure during transportation on carload samples of the same kind of coal is shown by the test and analyses of the other samples from North Dakota in the same report. In a mine sample (No. 1730) 19.5 per cent of the original moisture was retained, but in the carload sample No. 2365 from the same mine 52.1 per cent of the moisture content of the coal on arrival at the laboratory, or 42.5 per cent of the content when the coal left the mine, was retained after air drying. Mine samples Nos. 1935 and 1938 and car sample No. 2243 were taken from another mine. Sample No. 1935 retained 20.3 per cent and No. 1938 held 20 per cent of the moisture after air drying. The car sample No. 2243 retained 64.7 per cent of the moisture that reached the laboratory or 53.5 per cent of the moisture that left the mine.

The result of these comparisons indicates that subbituminous coal and lignite which contain a large amount of moisture give up a greater percentage of their moisture in the laboratory process of air drying, if taken from a fresh face and sent immediately from the mine to the laboratory in air-tight cans, than they do if exposed to the circulation of air in the mine, or in transit to the laboratory, or in storage while awaiting analysis.

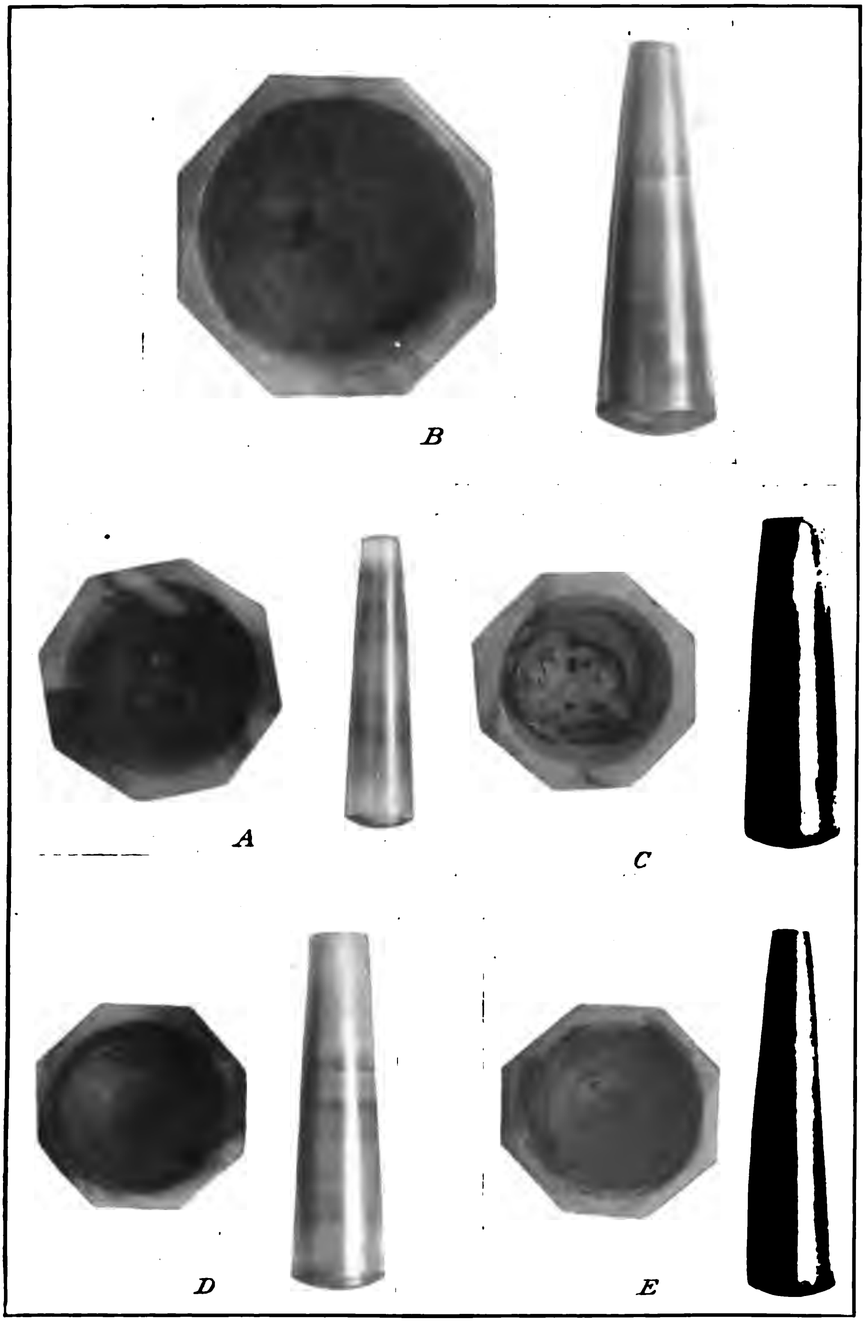
The conclusion is that upon exposure to the atmosphere in the mine, in transportation, or in storage, the relation to the coal of at least a part of the moisture content is so altered that it is not given up readily in the ordinary method of air drying. It is not known whether

[1] Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905; Bull. U. S. Geol. Survey No. 290, 1906, p. 135.

this is a physical or a chemical change. It is hoped that experimentation will be carried on which will determine the character of this alteration.

Inasmuch as the amount of weathering and the amount of moisture retained by the weathered sample will vary with an innumerable combination of conditions, the only uniformity in the air-drying loss of low-grade coal will be found in samples from unweathered coal analyzed as soon as received at the laboratory. The air contained in the interstices of the coal in the can probably has some effect on the moisture, but if the sample is ground in the mine so as to pass through a ¼-inch to ½-inch mesh and packed in the can the amount of air is reduced nearly to a minimum. A finer reduction of the fragments would probably allow the air in the pore spaces to affect the finer particles more readily, since the mass of a fragment is much smaller in proportion to its diameter and the surface exposed to the air is much greater in proportion to the mass in small pieces of coal than in large pieces. A mixture of large pieces with the spaces packed with smaller fragments would be the best way of reducing the effect of the air to a minimum, but this method would not produce a representative sample and consequently should not be used.

Samples of coal high in moisture, analyzed in commercial laboratories, show considerable variation in the amount of moisture from the same mine, due probably to different methods of sampling, to drying in transit, and to alteration of the relation of the moisture to the coal by exposure to the air—all causes which may be ultimately reduced to lack of uniformity in the methods of sampling and transportation to the laboratory. Discrepancies are generally due to the following circumstances: (1) Samples are not taken from fresh faces of unweathered coal; (2) samples are not cut uniformly from the face of the coal; (3) the coal is not ground and sealed in the mine or under atmospheric conditions similar to those existing at the face where the sample was taken; (4) the coal is not always ground and sealed immediately after being cut and is frequently exposed to the air for a considerable length of time; (5) the coal is not always pulverized to the same size and thoroughly mixed, quartered, and packed in an air-tight can; (6) the sample is not always sealed in an air-tight can packed full, but is frequently shipped to the laboratory in a box or sack which admits of more or less circulation of the atmosphere; (7) the sample is not always sent so as to reach the laboratory in the shortest possible time and is therefore exposed to the air for varying lengths of time; (8) the coal is not always analyzed as soon as it reaches the laboratory. It is hoped that in the future commercial samples will be taken by the method herein described, so that the results will be mutually comparable, as well as comparable with the Government work.



MORTARS AND PESTLES.

A. Showing adherence of powder of coal from the Roslyn bed at Clealum, Kittitas County.
B. Showing adherence of powder of coal from the Roslyn bed at Beekman, Kittitas County.
C. Showing poor adherence of powder of noncoking bituminous coals.
D. Showing adherence of powder of the best coking coals of Washington.
E. Showing adherence of powder of Pocahontas (West Virginia) coal.

COKING COAL OF WASHINGTON BY PISHEL TEST.

M. A. Pishel[1] found by experimentation on a large number of samples of coal from different parts of the United States that the best coking coal, when finely pulverized in an agate mortar, adheres very strongly both to the mortar and to the pestle and can be removed only by rubbing or washing, and that noncoking coal does not adhere either to the mortar or to the pestle. This test was applied to nearly all the coals sampled by the writer. In making the test a dry sample is selected from each bench in the bed, or from each part of a bench if the bed is not uniform. A small quantity of the coal is pulverized in a mortar until it will pass through a 100-mesh sieve, and after the pulverized coal has been poured from the mortar the amount and character of the adhesion of the powder to the pestle and the mortar are observed. Stages of adhesion range from that of a deep covering of greasy or gummy powder, resembling iron filings clustered on the poles of a magnet, which adheres so strongly to the surface that it can be removed with difficulty, to that of thin films of powder which will scarcely soil the finger. Between these two extremes was found to be complete gradation. Coal which adhered fairly well was found to produce a fair grade of coke. Coal which adhered only slightly formed a poorer grade of coke and then only under the most favorable conditions for coking. The scale of adhesion given by Pishel in describing his test is used in Table 3 of this report. By this scale coking coals are graded in respect to coking qualities as poor, medium, good, and excellent.

The author experimented while in the field with mortars of different composition to ascertain if possible whether the coal would adhere to substances other than agate. Porcelain, glass, earthenware, and iron mortars were used, and the powder of coking coal adhered to all; the powder adhered to a piece of flat glass just as well as to the mortar, but it was more difficult to reduce the powder to the proper degree of fineness on the flat surface. It appears that a powder must be of a certain degree of fineness in order to show the property of adhesion. Pocahontas (W. Va.) coal, powdered both on smooth and rough surfaces, was found to adhere provided the surface was not too soft or too rough to admit of the reduction of the particles to the proper size. In general a hard smooth surface is preferable, because the use of such a surface insures a finer and more uniform powder. (See Pl. II.)

The following table shows the results of the tests on the bituminous coals of Washington examined and on a sample of Pocahontas coal from Virginia:

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[1] A practical test for coking coals: Econ. Geology, vol. 3, 1908, pp. 265-275.

Results of Pishel coking test on bituminous coals of Washington.

Mine or operator.	Locality.	Coal bed.	Kind of coke produced.	Adherence to mortar when ground.	Ash in coal.	Remarks.
Pocahontas Consolidated Collieries	Pocahontas, W. Va	Pocahontas No. 3a	Excellent	Excellent	Low	Is coked.
Big Six Coal Co	Near Palmer	Pocahontas	Good	Good	Medium	Has been coked.
Black Carbon Coal Co	Pittsburg	Black carbon		Poor	High	
Carbon Coal Co	Bayne	No. 1	Good	Good	Low to medium	Cokes on forge.
Do	do	No. 2	do	do	Low	Do.
Carbon Hill Coal Co	Carbonado	No. 1 coking	do	do	High	Has been coked.
Do	do	No. 2 coking	do	do	do	Do.
Do	do	No. 3 coking	do	do	do	Do.
Do	do	Wingate	do	do	Low	Do.
Do	do	No. 1, north		Medium	Medium	
Do	do	No. 5		do	High	
Do	do	No. 9		Good	do	Cokes on forge.
Do	do	No. 11		do	do	Do.
Coast Coal Co	Pittsburg	Pittsburg		Poor	do	
Do	do	Lady Wellington		do	do	
Commonwealth Coal Co	Wilkeson	Windsor	Good	Good	do	Has been coked.
Denny-Renton Clay & Coal Co	Kummer			Poor	Medium	
Do	Taylor	No. 2		do	High	
Do	do	No. 4		do	Medium	
Do	do	No. 5		Medium	do	
Do	do	No. 6		do	do	
East Creek Coal Co	Ladd	No. 2	Good	Good	High	Do.
Do	do	No. 3		Poor	do	
Do	do	No. 4		do	do	
Evans Creek Coal Co	Montezuma	No. 2	Good	Good	do	Is coked.
Do	do	No. 3	do	do	do	Do.
Do	do	No. 4	do	do	Medium	Do.
Gale Creek Coal & Coke Co	Wilkeson	No. 1		do	Low	Cokes on forge.
Do	do	No. 2		do	do	Do.
Do	do	Queen		do	do	Do.
Green River Coal Co	Bayne	No. 1		Poor	High	
Do	do	No. 3		do	do	
Do	do	No. 5	Medium	Medium	Low to medium	Do.
Independent Coal Co	Cumberland	Lower bench		Poor	High	
Do	do	Upper bench		do	do	
Naval Coal Co	do	No. 4		Medium	do	
Do	do	No. 6, upper bench		do	do	
Do	do	No. 6, lower bench	Good	Good	Medium	Do.
Northwestern Improvement Co	Melmont	No. 2	Medium	Medium	High	Do.
Do	do	No. 3	do	do	Medium	Do.
Do	Ravensdale	do		Poor	do	
Do	do	No. 4		do	do	
Do	do	No. 5		do	do	
Do	do	McKay		do	Low	

Do.	do	Upper McKay		do	do	
Northwestern Improvement Co. No. 3	Ronald	Roslyn	Good	Good	Medium	Has been coked.
Northwestern Improvement Co. No. 2	Roslyn	do	Medium	Medium	do	Do.
Northwestern Improvement Co. No. 4	do	do	do	do	do	Do.
Northwestern Improvement Co. No. 5	do	do	Poor	Poor	do	Cokes slightly on forge.
Northwestern Improvement Co. No. 7	Clealum	do		do	do	Strong sinter.
Northwestern Improvement Co. No. 1	do	do		do	do	Weak sinter.
Northwestern Iron & Steel Co.	Ashford		Good	Good	High	Has been coked.
Occidental Colliery Co.	Bayne	No. 1	do	do	Medium	Cokes on forge.
Do.	do	No. 2	do	do	do	Do.
Do.	do	No. 3	do	do	do	Do.
Do.	do	No. 6		Poor	High	
Do.	do	No. 14, lower bench	Good	Good	Low	Do.
Do.	do	No. 14, upper bench	do	do	High	Do.
Pacific Coal & Oil Co.	Wilkeson			do	do	Do.
Pacific Coast Coal Co.	Burnett	No. 2	Good	do	Low	Has been coked.
Do.	do	No. 3	do	do	Medium	Do.
Do.	Franklin	Gem		Poor	do	
Do.	Black Diamond	McKay		do	Low	
Do.	do	Upper McKay		do	Low to medium	
Rose-Marshall Coal Co.	Cumberland	Harris		Medium	Low	
Roslyn Cascade Coal Co.	Ronald	Roslyn	Good	Good	Medium	Do.
Do.	do	Lower		do	Medium to high	
Roslyn Fuel Co.	Beekman	Roslyn	Good	do	Medium	Do.
Sunset Coal Co.	Cumberland	No. 1		Poor	do	
Do.	do	No. 2	Medium	Medium	High	Cokes on forge.
Do.	do	No. 3		Poor	do	
Surface exposure	Palmer Junction			Medium to good	do	
Tacoma Smelting Co.	Fairfax	No. 3	Good	Good	Medium	Is coked.
Do.	do	No. 7	do	do	High	Do.
Do.	do	Blacksmith	do	do	Medium	Cokes on forge.
Tunnel, sec. 21, T. 21 N., R. 7 E.	Bayne			do	High	
United Collieries Co.	Snoqualmie	No. 3	Good	do	Medium	Has been coked.
Do.	do	No. 4	do	do	do	Do.
Do.	do	No. 5	do	do	High	Do.
Wilkeson Coal & Coke Co.	Wilkeson	No. 2	do	do	Low to medium	Is coked.
Do.	do	No. 3	do	do	do	Do.
Do.	do	No. 7	do	do	do	Has been coked.

a Semibituminous.

IMPURITIES.

The impurities which have the most important effect upon the quality and commercial value of the Washington coals are sulphur, moisture, and ash.

SULPHUR.

The amount of sulphur in the coal of this State is generally very small. Only a few samples show more than 2 per cent. The sulphur is either disseminated through the main mass of the coal, or occurs in the form of lenses, nodules, and irregular masses of marcasite or pyrite. In the latter form the marcasite or pyrite is associated with other minerals, such as silica and iron, and is considered as ash when its amount is too small to be easily removed in preparing the coal for the market.

MOISTURE.

Moisture is present in amounts depending on the metamorphism of the coal. Anthracite has very little moisture. Bituminous coal has from 2 to 12 per cent, about half of which is given up on air drying. Subbituminous coal has from 9 to 25 per cent of moisture, and gives up from one-third to three-fourths of this when air-dried. As a general rule coal that is high in moisture slacks on exposure to air and sparks readily under forced draft. It is therefore of much less commercial value than coal that is low in moisture.

ASH.

The amount of ash in a coal and its condition and origin have very great effects both on the preparation of the coal for use and on its market value, and accordingly the cost of reducing the amount of ash in a coal as it is mined is one of the most important factors in determining the economic value of a coal bed. Washington coal as it comes from the mine has a large amount of ash, due to varying combinations of inorganic material derived from the vegetable matter from which the coal was formed, extraneous material which became mixed more or less intimately with the carbonaceous material during accumulation, vein material deposited after the coal was formed, and broken or shaly roof or floor material that "slacks," scales off, or mixes with the coal in mining.

The ash derived from the vegetal material which formed the coal consists of the remains of the organisms contributary to the formation of the coal, and it may be termed "original" or "residual." Those plants which contain a large amount of inorganic material will tend to produce a coal of high ash content, other conditions being equal.

Addition to the residual ash is brought about by several processes and conditions. The rate of accumulation of the layers of peat from which the coal was formed is one of the factors. If a layer 1 inch thick accumulates in so short a time that the organic matter does not have a chance to decay, the resulting coal will be lower in ash than if the layer had resulted from a relatively long period of accumulation and far advanced decay.

Ash that is more or less intimately mixed with the coal but not derived from the original organic débris is either of eolian origin or has been laid down as sediment or deposited from solution. In some places ash of this kind has been deposited in the form of minute veins by precipitation from mineralized waters after the coal was formed. Many beds of peat, such as those of the northern part of Iowa and those of the salt marshes bordering the Atlantic coast, contain a large amount of ash in the form of dust or sand derived from the adjoining regions. The amount of meteoric material included in coal depends on the length of time required for the deposition of the organic material; on whether climatic, physiographic, and geologic conditions of the adjoining region were favorable to slow or rapid formation of dust or sand; and on whether meteoric conditions were favorable to the transportation of dust to the bog or marsh in which the coal measures were forming.

The intimately mixed ash resulting from sedimentation is brought from adjacent land areas by surface waters. This sediment is usually very fine and is deposited as silt in the interstices between the fragments of organic material as they accumulate in the bog or marsh. A very small amount of this extraneous matter is not visible in coal, but larger amounts produce the various stages of impure coal, bony coal, bone, carbonaceous shale, and the like.

Incoming water carries in solution varying quantities of mineral matter. If the water of the bog or marsh is not drained off, but is removed by evaporation, the minerals will sooner or later reach their saturation point and will be precipitated, forming minerals that mix with the particles of organic material and form a part of the ash.

The ash that is separate from the coal occurs as partings, lenses, nodules, concretions, and veins. It originates at the time of the formation of the coal, in part from eolian or meteoric dust or sand, but principally from mineral matter dissolved or suspended in water. It may also be formed in the bed after the organic material has been deposited during the different stages in the alteration of the coal.

If at any time in the formation of a coal bed conditions are such that the organic material in the bog or marsh decays completely, the ash of the bed will accumulate in a layer free from carbonaceous matter. This layer will be a parting in the bed if it is not removed before the further deposition of the coal-forming substances. If conditions for a short time allow the carrying of extraneous material into the area of accumulation greatly in excess of the rate of formation of the coal, it will be deposited in a layer or lens in the coal.

In places small veins of calcite, selenite, quartz, or other minerals occur in the coal. These veins probably originate by deposition from mineralized water in the joints of the coal at some stage in its devolatilization or development. In the State of Washington veins of calcite up to half an inch in thickness occur in the lower part of the bed No. 2 at the Ladd mine (p. 160). Ash also occurs in the form of nodules, such as "niggerheads" and "sulphur" balls. The mode of origin of these nodules is not known, although it is believed that they were formed during the deposition or subsequent to the formation of the coal. They vary from a fraction of an inch to several feet in maximum diameter. Several layers of this material occur in the Roslyn bed as definite partings and extend for some distance. The great specific gravity of impurities of this kind, together with their other physical characteristics, makes it possible to separate them from the lighter coal by washing and from the lump coal by picking.

The amount of ash in commercial coal depends to a large extent on the character of the roof and floor and the amount and prominence of the joints. In some of the mines in the area of low-grade coal in Thurston, Lewis, and Cowlitz counties the rocks overlying and underlying the beds are very poorly indurated and are consequently mixed with the coal in mining. In some places the rocks are indurated, but they disintegrate on exposure and break off in slabs which mingle with the coal. Unless great care is taken to remove this extraneous material, the amount of ash is likely to be so large as to materially reduce the value of the commercial coal. In the areas of high-grade bituminous coking coals the coal is minutely jointed. The joints affect not only the coal, but many of the partings, and frequently the roof and floor, so that it requires the most refined methods of washing to remove the impurities that become mixed with the coal during the process of mining.

With very few exceptions, the Washington coal beds contain one or more partings of sand, shale, or clay, some of which material mixes with the coal in mining and therefore increases the ash in the commercial coal. The percentages of ash in the analyses accompanying this report are almost invariably higher than they would have been if clean coal had been taken. The partings are either too thin to be removed economically or they resemble the coal so closely in physical properties that they can not be completely separated by any method so far devised.

COMPARATIVE QUALITY AND DISTRIBUTION OF THE COALS.

The coal of the State ranges from low-grade subbituminous to anthracite. In general, variation in the character and quality of the coals is regional rather than local, although many of the beds are locally burned out or altered to coke. In his reports on Washington coal, Willis[1] makes the following statement regarding the coal in the Green River district near Black Diamond: "Beyond the area of this mechanical influence the coal changes into lignite by transition within a single bed." The name of the bed concerning which this statement was made is not given. The writer looked for evidence to verify this statement while in the field, but was unable to find any. It seems possible from Willis's report that he considered that the subbituminous bed at Danville might be the continuation of the McKay bed at Black Diamond. The identity of these two beds has not been established, and at present all the evidence available points to the conclusion that they are different beds. In general, anthracite and bituminous coal occur nearer the main axis of the Cascade Mountains, and subbituminous coal occurs farther from the range and nearer the center of the Puget Sound depression. In the depression between Puget Sound and Columbia River the coal is subbituminous. None of the coals at the mines and prospects visited by the writer were typical brown lignite. The coal at the Union Coal Co.'s mine, near Littell, and that in Cowlitz County are brownish black in color, and probably they are nearest to true lignite. The coal at the Hannaford mine, at Tono, is the only distinctly subbituminous coal in the district. The Mendota coal is on the border line between the two groups, but should probably be classed as a low-grade subbituminous coal. It is slightly brownish black, contains much more moisture than the average subbituminous coal, and much less moisture than the lignite of North Dakota. In the western part of King County subbituminous coal occurs in an area lying between Renton, Danville, and sec. 13, T. 24 N., R. 6 E. This coal is grayish black, contains a large amount of moisture, and slacks when exposed to the direct rays of the sun. East of this area and south of Snoqualmie River, in King County, most of the coal is bituminous except where it is altered locally by igneous action to coke. At Kummer, south of Franklin, several beds contain a large amount of moisture and slack on exposure to the sun. The coal of Kittitas and Pierce counties is bituminous. In Pierce County the coal from the lower part of the formation carries less ash and has a greater heating value than that from beds higher in the formation. The bituminous coal

[1] Willis, Bailey, Some coal fields of Puget Sound: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p. 402, and Willis, Bailey, and Smith, G. O., Tacoma folio (No. 54), Geol. Atlas U. S., U. S. Geol. Survey, 1899.

at Ladd appears to be the southward continuation of the bituminous area of Pierce County. The coal of Clallam County has been described in previous reports as lignite, but the coal of that area with which the writer is familiar lacks the physical properties of lignite and should be classed as bituminous. It is possible, however, that coal from other beds in the district is subbituminous or even lignite. The coal of the Bellingham and Skagit River regions is reported much jointed, very friable, and so high in fixed carbon that it is considered a very good grade of bituminous or, possibly, semibituminous coal. Specimens of coal from Skagit County, which the writer saw at the Alaska-Yukon-Pacific Exposition, indicated that it was nearer semibituminous than any other coal seen in the State. The anthracite district at the head of Cowlitz River, in Lewis County, is the only one visited by the writer, although a second anthracite area is reported on Glacier Creek, near Mount Baker, in Whatcom County.

COMMERCIAL USE OF THE COAL.

The commercial value of the Washington coal depends chiefly on the composition of the particular coals and on the distance of the mine from markets.

The anthracite is not used at the present time for lack of transportation facilities. The demand for anthracite for domestic use is great, but the prevailing price is so high that the better grades of bituminous coal must be utilized instead.

The bituminous coal has various uses. The coals from the McKay field in King County, from Pittsburg and the easternmost beds at South Willis, from beds Nos. 3 and 4 at Ladd, and from the Roslyn bed at Clealum and Roslyn are free burning and noncoking. They burn rapidly and produce a very hot fire, but the fire must be fed more frequently and with smaller quantities of coal than when coking coal is used. Coals of this type that are not too high in ash have a good heating value, and are valuable for domestic use and for generating steam, and the Roslyn coal is used extensively in the eastern part of the State. The coals from the remainder of the eastern part of King County, from the rest of Pierce County, from bed No. 2 at Ladd, from Cokedale, in Skagit County, and from the west end of the Roslyn field coke to a greater or less degree. Coal from Cokedale, Snoqualmie, Burnett, Wilkeson, Carbonado, Fairfax, Montezuma, and bed No. 2 at Ladd have been used for coking, and at the present time practically the entire output of the Wilkeson, Fairfax, and Montezuma mines is being used in the manufacture of metallurgical and foundry coke. Coke of various grades has been made from the other coals, and those that have not been coked show fair coking tendencies by the Pishel test. (See p. 31.) All these coals are high in volatile matter and produce a hot fire; they ignite easily and, on account of their coking tendencies, hold the fire much longer than the free-burning coals. They are used very generally for domestic purposes and for generating steam. The coal from Burnett, Wilkeson, Carbonado, the west end of the Roslyn field, and several other places in the region is used to a considerable extent in the manufacture of illuminating gas. Some of the coal, notably the washed coal from Wilkeson, Fairfax, and Montezuma, is used in blacksmithing, but the finer kinds of welding are done with coal imported from the Eastern States.

Experiments on both classes of bituminous coal, designed to test their suitability for naval use, indicate that their content of volatile combustible matter is too high to permit their use in the boilers now in service, because they produce too high temperature in the uptake and an excessive amount of soot. The introduction of furnaces that will consume the gases before they leave the combustion chamber might make possible the employment of many of these coals on naval vessels. They are now used by Pacific steamships whose requirements are not so exacting as those of the Navy, by railroads, and for domestic and commercial purposes.

Subbituminous coal is produced in the vicinity of Issaquah, Newcastle, Renton, Cedar Mountain, and Danville, in King County, and near Tono, in Thurston County. On account of the large amount of moisture in this kind of coal, it swells and crumbles readily when placed on a fire. With forced draft, the pieces resulting from the crumbling are blown out with the smoke in considerable quantities, so that much of the fuel is wasted and in inflammable structures considerable risk of fire is entailed. Owing to the high percentage of combustible volatile matter in the coal, a large amount of soot is formed and the temperature in the uptake is rather high. This coal is used mainly for domestic purposes, or by steam boilers having natural draft. A fire made with this coal in furnaces and stoves is very hot when there is sufficient natural draft but cools very rapidly when the supply of air is shut off. As a rule the coal does not hold a fire nearly so long as bituminous coal. Subbituminous coal is used by some of the steamships of the Pacific Coast Steamship Co., and to some extent by railroads, besides supplying the domestic and commercial needs of the cities and towns near Puget Sound.

The low-grade subbituminous coal from Thurston, Lewis, and Cowlitz counties is high in moisture and crumbles readily when exposed to the sun or air. It must be used within a short time after it is brought from the mine or it will crumble to pieces and fall through the grate. When placed upon a hot fire, it crumbles and swells very rapidly, and forms a great many sparks. Owing to the high percentage of volatile combustible matter contained in it a great deal of soot is formed unless proper precautions are taken to assure the compl combustion of the gases. The great amount of moisture in this coal gives it a lower heating value than the other coals in the State, and consequently it is not in very great demand except where better coal is scarce and high in price. Most of this coal is used by the local trade or is shipped south, away from the centers of mining of the coal of better grades. It is used almost entirely for domestic purposes and for stationary boilers with natural draft.

The rapid growth in the utilization of producer gas for the generation of power is opening a way for the use of low-grade subbituminous coal and lignite. Campbell[1] sets forth the value of these low-grade coals in the production of producer gas, and points out as essential features the facts that low-grade coal yields practically double or more than double the amount of power in the producer that it will yield in a steam plant, and that low-grade fuels, such as North Dakota and Texas lignite and Florida peat, yield more power in the producer than the best West Virginia coal under the ordinary type of steam boiler. These experimental results make it hopeful that it will soon be possible to build and conduct producer plants satisfactorily on a commercial scale. Low-grade coal, which now is disposed of with difficulty, will then find a ready market.

[1] Campbell, M. R., Recent improvements in the utilization of coal: Econ. Geology, vol. 2, April-May, 1907.

Analyses of coal samples from the State of Washington.

[A. C. Fieldner, chemist in charge.]

Name of mine or form of exposure.	Laboratory No.	Location.				Page.[a]	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
		Quarter.	Section.	Township.	Range.				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Clallam County.																			
Fuca, 6 miles east of Clallam.	10030	....	25	32 N.	12 W.	77	3.4	As received	11.2	40.0	36.2	12.57	5.10	5.97	56.70	0.90	18.76	5,825	10.490
								Air dried	8.1	41.4	37.5	13.01	5.28	5.79	58.70	.93	16.29	6,030	10,860
								Dry coal	....	45.0	40.8	14.16	5.75	5.33	63.88	1.01	9.87	6,565	11,810
								Pure coal	....	52.5	47.5	....	6.70	6.21	74.42	1.18	11.49	7,645	13,760
Cowlitz County.[b]																			
Prospect 12 miles west of Kelso.	[c]6760	....	.....	9 N.	4 W.	79	....	As received	15.24	36.28	29.54	18.94	4.39	....	....	....	....	....	....
								Dry coal	....	42.80	34.85	22.35	5.18	....	....	....	....	....	....
								Pure coal	....	55.12	44.88	....	....	....	....	....	....	....	....
Do.	[d]6760	....	.....	9 N.	4 W.	79	....	As received	22.22	33.30	27.11	17.37	4.03	....	....	....	....	....	....
								Dry coal	....	42.81	34.86	22.33	5.18	....	....	....	....	....	....
								Pure coal	....	55.12	44.88	....	....	....	....	....	....	....	....
Do.	6761	....	.....	9 N.	4 W.	79	....	As received	16.26	36.33	30.05	17.36	4.61	....	....	....	....	....	....
								Dry coal	....	43.38	35.89	20.73	5.51	....	....	....	....	....	....
								Pure coal	....	54.72	45.28	....	....	....	....	....	....	....	....
King County.																			
Prospect 3 miles north of Issaquah.	9291	SW.	13	24 N.	6 E.	81	9.7	As received	17.5	31.2	38.5	12.77	0.37	5.85	52.11	1.08	27.82	5,185	9,330
								Air dried	8.7	34.5	42.7	14.14	.41	5.28	57.71	1.20	21.26	5.740	10,330
								Dry coal	....	37.8	46.7	15.48	.45	4.73	63.17	1.31	14.86	6,285	11,310
								Pure coal	....	44.7	55.3	....	.53	5.60	74.74	1.55	17.58	7,435	13,380

[a] Section of coal bed and description of sample are given on the page indicated.
[b] These analyses were not made in the fuel-testing laboratory of the Geological Survey.
[c] Finely ground.
[d] Coarsely ground.

Analyses of coal samples from the State of Washington—Continued.

King County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location. Quarter.	Location. Section.	Location. Township.	Location. Range.	Page.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Heat value. Calories.	Heat value. British thermal units.
Grand Ridge, 3 miles east of Issaquah, No. 1 bed.	8544	NW.	26	24 N.	6 E.	81	6.1	As received	14.2	30.3	43.8	11.66	0.36	5.77	56.70	1.06	24.45	5,575	10,040
								Air dried	8.7	32.3	46.6	12.42	.39	5.42	60.38	1.13	20.26	5,940	10,690
								Dry coal	....	35.3	51.1	13.59	.42	4.89	66.11	1.24	13.75	6,500	11,700
								Pure coal	....	40.9	59.1	....	.49	5.66	76.51	1.44	15.90	7,525	13,550
Grand Ridge, 3 miles east of Issaquah, No. 2 bed.	8545	NW.	26	24 N.	6 E.	81	3.8	As received	13.8	32.4	36.1	17.70	.49	5.64	51.24	.95	23.98	5,075	9,140
								Air dried	10.4	33.7	37.5	18.40	.51	5.43	53.26	.99	21.41	5,275	9,500
								Dry coal	....	37.6	41.9	20.53	.57	4.77	59.43	1.10	13.60	5,885	10,600
								Pure coal	....	47.3	52.7	....	.72	6.00	74.77	1.38	17.13	7,395	13,310
Grand Ridge, 3 miles east of Issaquah, No. 3 bed.	11736	NE.	26	24 N.	6 E.	81	9.0	As received	15.9	36.0	38.5	9.6	.49	....	....	....	....	5,535	9,970
								Air dried	7.6	39.6	42.3	10.5	.54	....	....	....	....	6,085	10,950
								Dry coal	....	42.8	45.8	11.4	.58	....	....	....	....	6,585	11,850
								Pure coal	....	48.4	51.6	....	.65	....	....	....	....	7,430	13,380
Grand Ridge, 3 miles east of Issaquah, No. 4 bed.	11737	NE.	26	24 N.	6 E.	82	9.6	As received	15.6	33.4	30.4	20.6	2.27	....	....	....	....	4,660	8,390
								Air dried	6.6	37.0	33.6	22.8	2.51	....	....	....	....	5,155	9,280
								Dry coal	....	39.6	36.0	24.4	2.69	....	....	....	....	5,525	9,940
								Pure coal	....	52.4	47.6	....	3.56	....	....	....	....	7,310	13,160
Grand Ridge, 3 miles east of Issaquah, No. 7 bed.	11738	NE.	26	24 N.	6 E.	82	10.6	As received	16.5	34.6	36.4	12.5	.38	....	....	....	....	5,325	9,580
								Air dried	6.5	38.8	40.7	14.0	.42	....	....	....	....	5,955	10,720
								Dry coal	....	41.5	43.5	15.0	.45	....	....	....	....	6,370	11,470
								Pure coal	....	48.8	51.2	....	.53	....	....	....	....	7,495	13,490
Grand Ridge, 3 miles east of Issaquah, washed coal.	9883	....	26	24 N.	6 E.	82	8.5	As received	18.0	33.5	34.4	14.08	.38	5.95	51.74	1.03	26.82	5,045	9,080
								Air dried	10.4	36.6	37.6	15.39	.41	5.47	56.55	1.13	21.05	5,515	9,920
								Dry coal	....	40.8	42.0	17.18	.46	4.82	63.12	1.26	13.16	6,155	11,080
								Pure coal	....	49.3	50.7	....	.56	5.82	76.21	1.52	15.89	7,430	13,370
Issaquah at Issaquah, No. 4 bed.	8542	NE.	33	24 N.	6 E.	83	8.0	As received	17.9	29.2	43.6	9.3	.35	....	....	....	....	5,450	9,810
								Air dried	10.7	31.8	47.4	10.1	.38	....	....	....	....	5,925	10,660
								Dry coal	....	35.6	53.1	11.3	.43	....	....	....	....	6,635	11,940
								Pure coal	....	40.1	59.9	....	.48	....	....	....	....	7,480	13,460

Issaquah at Issaquah, No. 5 bed.	8543	SE.	33	24 N.	6 E.	83	6.6	As received	15.1	29.4	44.2	11.35	1.12	5.65	55.58	1.09	25.21	5,530	9,960
								Air dried	9.1	31.4	47.4	12.15	1.20	5.27	59.51	1.17	20.70	5,920	10,660
								Dry coal	....	34.6	52.0	13.36	1.32	4.69	65.43	1.28	13.92	6,510	11,720
								Pure coal	....	39.9	60.1	....	1.52	5.41	75.52	1.48	16.07	7,515	13,530
Superior, 1½ miles southwest of Issaquah, Main bed.	8548	SE.	32	24 N.	6 E.	84	5.3	As received	12.8	28.5	43.6	15.11	.68	5.56	55.68	1.11	21.86	5,025	10,120
								Air dried	7.9	30.1	46.0	15.96	.72	5.25	58.80	1.17	18.10	5,940	10,690
								Dry coal	....	32.7	50.0	17.32	.78	4.75	63.83	1.25	12.05	6,445	11,600
								Pure coal	....	39.5	60.5	....	.94	5.74	77.21	1.54	14.57	7,795	14,030
Superior, 1½ miles southwest of Issaquah, No. 0 bed.	8547	SE.	32	24 N.	6 E.	84	4.3	As received	12.4	29.7	41.8	16.1	1.61	....	....	....	....	5,480	9,860
								Air dried	8.5	31.0	43.7	16.8	1.68	....	....	....	....	5,725	10,310
								Dry coal	....	33.9	47.7	18.4	1.84	....	....	....	....	6,255	11,260
								Pure coal	....	41.5	58.5	....	2.25	....	....	....	....	7,665	13,800
Ford at Coal Creek, Muldoon bed.	9163	SE.	25	24 N.	5 E.	86	9.7	As received	14.3	31.5	42.4	11.75	.44	5.84	56.12	1.25	24.60	5,535	9,960
								Air dried	5.1	34.9	47.0	13.01	.49	5.27	62.15	1.38	17.70	6,130	11,040
								Dry coal	....	36.8	49.5	13.72	.51	4.96	65.51	1.46	13.84	6,460	11,630
								Pure coal	....	42.7	57.3	....	.59	5.75	75.93	1.69	16.04	7,490	13,480
Do.	9166	SE.	27	24 N.	5 E.	86	7.2	As received	13.1	34.7	39.5	12.74	.71	5.76	56.45	1.35	22.99	5,535	9,960
								Air dried	6.3	37.4	42.6	13.73	.76	5.34	60.83	1.45	17.89	5,965	10,730
								Dry coal	....	39.9	45.4	14.66	.82	4.96	64.94	1.55	13.07	6,365	11,460
								Pure coal	....	46.8	53.2	....	.96	5.81	76.10	1.82	15.31	7,460	13,430
Do.	9165	SE.	26	24 N.	5 E.	86	7.1	As received	12.8	35.8	40.9	10.48	.55	5.83	58.92	1.30	22.86	5,760	10,370
								Air dried	6.2	38.5	44.0	11.28	.59	5.43	63.42	1.46	17.82	6,200	11,160
								Dry coal	....	41.1	46.9	12.03	.63	5.05	67.62	1.56	13.11	6,610	11,900
								Pure coal	....	46.7	53.3	....	.72	5.74	76.86	1.77	14.91	7,515	13,520
Ford at Coal Creek, No. 3 bed.	9168	SE.	25	24 N.	5 E.	86	8.6	As received	14.5	30.9	43.3	11.30	.36	5.80	56.23	1.08	25.23	5,565	10,010
								Air dried	6.4	33.8	47.4	12.36	.39	5.30	61.52	1.18	19.25	6,090	10,960
								Dry coal	....	36.1	50.7	13.22	.42	4.90	65.76	1.26	14.44	6,505	11,710
								Pure coal	....	41.6	58.4	....	.48	5.65	75.78	1.45	16.64	7,500	13,500
Do.	9164	SE.	25	24 N.	5 E.	86	9.7	As received	14.5	32.5	45.6	7.37	.42	5.88	59.60	1.05	25.68	5,790	10,420
								Air dried	5.2	36.0	50.6	8.16	.47	5.32	66.00	1.16	18.89	6,410	11,540
								Dry coal	....	38.0	53.4	8.61	.49	4.99	69.67	1.23	15.01	6,765	12,180
								Pure coal	....	41.6	58.4	....	.54	5.46	76.23	1.36	16.41	7,405	13,330
Ford at Coal Creek, No. 4 bed.	9167	SE.	25	24 N.	5 E.	86	8.9	As received	14.8	33.3	43.6	8.26	.37	6.03	58.48	1.34	25.52	5,685	10,230
								Air dried	6.5	36.5	47.9	9.07	.41	5.53	64.19	1.47	19.33	6,240	11,240
								Dry coal	....	39.1	51.2	9.70	.44	5.14	68.64	1.57	14.51	6,675	12,010
								Pure coal	....	43.3	56.7	....	.49	5.69	76.01	1.74	16.07	7,390	13,300
Bagley at Coal Creek, Bagley No. 1 bed.	9170	SE.	26	24 N.	5 E.	87	6.6	As received	12.1	36.8	40.7	10.41	.34	5.75	58.15	1.37	23.98	5,785	10,410
								Air dried	5.8	39.4	43.6	11.15	.36	5.38	62.26	1.47	19.38	6,195	11,150
								Dry coal	....	41.9	46.3	11.84	.39	5.01	66.12	1.56	15.08	6,580	11,840
								Pure coal	....	47.5	52.5	....	.44	5.68	75.00	1.77	17.11	7,465	13,420

Analyses of coal samples from the State of Washington—Continued.

King County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location. Quarter.	Section.	Township.	Range.	Page.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Volatile matter.	Fixed carbon.	Ash.	Ultimate. Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Heat value. Calories.	British thermal units.
Bagley at Coal Creek, Bagley No. 2 bed.	9171	NE.	25	24 N.	5 E.	87	4.6	As received	9.3	39.9	36.8	14.00	3.82	5.67	57.85	1.19	17.47	5,900	10,620
								Air dried	4.9	41.9	38.5	14.68	4.00	5.41	60.64	1.25	14.02	6,185	11,140
								Dry coal	....	44.0	40.6	15.43	4.21	5.11	63.76	1.31	10.18	6,505	11,710
								Pure coal	....	52.1	47.9	....	4.98	6.04	75.40	1.55	12.03	7,690	13,850
Do	9169	NE.	25	24 N.	5 E.	87	7.5	As received	12.3	36.8	39.7	11.16	.89	5.77	57.75	1.21	23.22	5,735	10,320
								Air dried	5.2	39.7	43.0	12.07	.96	5.34	62.43	1.31	17.89	6,200	11,160
								Dry coal	....	41.9	45.4	12.73	1.02	5.02	65.86	1.38	13.99	6,540	11,780
								Pure coal	....	48.0	52.0	....	1.17	5.75	75.47	1.58	16.03	7,495	13,490
Denny-Renton at Renton, No. 1 bed.	9154	SW.	17	23 N.	5 E.	89	8.1	As received	16.3	32.1	39.4	12.16	.48	5.77	53.58	1.33	26.68	5,230	9,410
								Air dried	8.9	35.0	42.9	13.23	.52	5.30	58.30	1.45	21.20	5,690	10,240
								Dry coal	....	38.4	47.1	14.52	.57	4.73	63.99	1.59	14.60	6,245	11,240
								Pure coal	....	44.9	55.1	....	.67	5.53	74.86	1.86	17.08	7,305	13,150
Do	9155	NW.	20	23 N.	5 E.	89	8.9	As received	16.8	32.2	39.1	11.86	.43	5.92	53.60	1.28	26.91	5,215	9,390
								Air dried	8.7	35.4	42.9	13.02	.47	5.41	58.84	1.40	20.86	5,725	10,300
								Dry coal	....	38.7	47.0	14.25	.52	4.87	64.42	1.54	14.40	6,265	11,280
								Pure coal	....	45.2	54.8	....	.61	5.68	75.13	1.80	16.78	7,310	13,160
Renton at Renton, No. 2 bed.	9158	NE.	20	23 N.	5 E.	90	7.2	As received	14.5	31.8	38.8	14.85	.68	5.60	53.24	1.18	24.45	5,185	9,330
								Air dried	7.9	34.3	41.8	16.00	.73	5.17	57.38	1.27	19.45	5,585	10,060
								Dry coal	....	37.2	45.4	17.37	.80	4.67	62.29	1.37	13.50	6,065	10,920
								Pure coal	....	45.0	55.0	....	.97	5.65	75.39	1.66	16.33	7,340	13,210
Renton at Renton, No. 3 bed.	9159	NE.	20	23 N.	5 E.	91	7.2	As received	14.6	34.0	41.5	9.9	.44	....	....	....	....	5,600	10,070
								Air dried	8.0	36.6	44.7	10.7	.47	....	....	....	....	6,030	10,860
								Dry coal	....	39.8	48.6	11.6	.52	....	....	....	....	6,555	11,800
								Pure coal	....	45.0	55.0	....	.59	....	....	....	....	7,420	13,360
Do	9160	NE.	20	23 N.	5 E.	90	8.1	As received	14.4	36.1	42.0	7.5	.60	....	....	....	....	5,875	10,580
								Air dried	6.9	39.2	45.7	8.2	.65	....	....	....	....	6,395	11,510
								Dry coal	....	42.1	49.1	8.8	.70	....	....	....	....	6,865	12,360
								Pure coal	....	46.2	53.8	....	.77	....	....	....	....	7,525	13,540

Do.	9157	SE.	17	23 N.	5 E.	91	7.5	As received	14.7	33.2	40.5	11.59	.47	5.95	55.37	1.20	25.33	5,485	9,870
								Air dried	7.8	35.9	43.8	12.53	.51	5.54	59.80	1.39	20.17	5,930	10,670
								Dry coal		38.9	47.5	13.59	.55	5.05	64.93	1.51	14.37	6,430	11,570
								Pure coal		45.0	55.0		.64	5.84	75.14	1.75	16.63	7,440	13,390
Do.	9156	SE.	17	23 N.	5 E.	90	7.2	As received	14.2	35.5	42.7	7.58	.68	5.89	59.25	1.38	25.22	5,865	10,550
								Air dried	7.5	38.3	46.0	8.17	.73	5.49	63.85	1.49	20.27	6,320	11,370
								Dry coal		41.4	49.8	8.84	.79	5.02	69.07	1.61	14.67	6,835	12,300
								Pure coal		45.4	54.6		.87	5.51	75.77	1.77	16.08	7,500	13,500
Do.	9161	SE.	19	23 N.	5 E.	91	10.0	As received	16.3	31.9	43.4	8.42	.37	6.20	57.11	1.27	26.63	5,615	10,100
								Air dried	7.0	35.5	48.2	9.35	.41	5.65	63.46	1.41	19.72	6,240	11,230
								Dry coal		38.1	51.8	10.06	.44	5.24	68.21	1.52	14.53	6,705	12,070
								Pure coal		42.4	57.6		.49	5.83	75.84	1.69	16.15	7,455	13,420
Do.	9162	SE.	20	23 N.	5 E.	90	9.5	As received	15.0	35.4	43.8	5.77	.54	6.16	59.73	1.37	26.43	5,975	10,750
								Air dried	6.1	39.1	48.4	6.38	.60	5.64	66.00	1.51	19.87	6,600	11,880
								Dry coal		41.6	51.6	6.79	.64	5.28	70.27	1.61	15.41	7,030	12,650
								Pure coal		44.7	55.3		.69	5.66	75.39	1.73	16.53	7,540	13,570
Do.	2455	SE.	20	23 N.	5 E.	90	9.9	As received	16.2	35.7	39.3	8.8	.46						
								Air dried	7.0	39.6	43.6	9.8	.51						
								Dry coal		42.5	46.9	10.6	.55						
								Pure coal		47.5	52.5		.62						
Do.	2456	NE.	20	23 N.	5 E.	91	12.9	As received	18.0	35.1	39.1	7.8	.43					5,560	10,010
								Air dried	5.8	40.4	44.9	8.9	.49					6,380	11,490
								Dry coal		42.8	47.7	9.5	.52					6,775	12,200
								Pure coal		47.3	52.7		.57					7,485	13,480
Renton at Renton, washed pea coal.	2687		20	23 N.	5 E.	92	10.7	As received	10.0	31.4	41.1	11.53	.61	5.57	56.51	1.16	24.62	5,520	9,940
								Air dried	6.0	35.1	46.0	12.91	.68	4.91	63.28	1.30	16.92	6,185	11,130
								Dry coal		37.4	48.9	13.73	.73	4.51	67.31	1.38	12.34	6,575	11,840
								Pure coal		43.3	56.7		.84	5.23	78.02	1.60	14.31	7,625	13,720
Renton at Renton, run-of-mine coal.	2686		20	23 N.	5 E.	92	9.6	As received	14.3	33.0	41.3	11.37	.72	5.73	57.27	1.17	23.74	5,670	10,210
								Air dried	5.2	36.6	45.6	12.58	.80	5.16	63.35	1.29	16.82	6,275	11,290
								Dry coal		38.5	48.2	13.27	.84	4.83	66.83	1.37	12.86	6,615	11,910
								Pure coal		44.4	55.6		.97	5.57	77.05	1.57	14.84	7,630	13,730
Danville at Danville.	9323	SW.	24	22 N.	6 E.	93	10.9	As received	18.1	32.6	41.3	8.0	.51					5,450	9,810
								Air dried	8.1	36.5	46.4	9.0	.57					6,115	11,010
								Dry coal		39.8	50.4	9.8	.62					6,650	11,970
								Pure coal		44.1	55.9		.69					7,375	13,280
Ravensdale No. 1 at Ravensdale, No. 3 bed.	9266	NE.	36	22 N.	6 E.	94	3.6	As received	9.0	35.3	43.5	12.17	.95	5.37	61.90	1.40	18.21	6,195	11,150
								Air dried	5.6	36.7	45.1	12.62	.99	5.16	64.21	1.45	15.57	6,425	11,570
								Dry coal		38.8	47.8	13.37	1.04	4.80	68.02	1.54	11.23	6,810	12,250
								Pure coal		44.9	55.1		1.20	5.54	78.52	1.78	12.96	7,860	14,140

Analyses of coal samples from the State of Washington—Continued.

King County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location. Quarter.	Location. Section.	Location. Township.	Location. Range.	Page.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Heat value. Calories.	Heat value. British thermal units.
Ravensdale No. 1 at Ravensdale, No. 4 bed.	9267	NE.	36	22 N.	6 E.	91	3.0	As received	7.4	37.4	44.0	11.24	0.51	5.63	63.91	1.52	17.19	6,390	11,500
								Air dried	4.5	38.6	45.3	11.59	.53	5.46	65.89	1.57	14.96	6,585	11,850
								Dry coal	......	40.4	47.5	12.14	.55	5.20	69.03	1.64	11.44	6,900	12,420
								Pure coal	......	46.0	54.0	......	.63	5.92	78.55	1.87	13.03	7,855	14,140
Ravensdale No. 1 at Ravensdale, No. 5 bed.	9270	NW.	36	22 N.	6 E.	94	4.1	As received	9.2	38.0	45.6	7.16	.35	5.57	66.63	1.53	18.76	6,565	11,820
								Air dried	5.3	39.7	47.5	7.47	.37	5.33	69.48	1.60	15.75	6,845	12,320
								Dry coal	......	41.9	50.2	7.89	.39	5.00	73.41	1.69	11.62	7,235	13,020
								Pure coal	......	45.5	54.5	......	.42	5.43	79.70	1.83	12.62	7,850	14,130
Do.	9274	NE.	36	22 N.	6 E.	94	2.9	As received	8.1	37.2	42.7	11.96	.29	5.47	61.85	1.43	19.00	6,195	11,150
								Air dried	5.1	38.3	44.0	12.32	.30	5.30	63.71	1.47	16.90	6,380	11,480
								Dry coal	......	40.5	46.5	13.02	.32	4.97	67.33	1.56	12.80	6,745	12,140
								Pure coal	......	46.5	53.5	......	.37	5.69	77.41	1.79	14.74	7,750	13,950
Do.	9271	NE.	36	22 N.	6 E.	91	3.9	As received	9.5	35.7	39.2	15.63	.70	5.33	57.83	1.53	18.98	5,770	10,390
								Air dried	5.7	37.2	40.8	16.27	.73	5.10	60.18	1.59	16.13	6,005	10,810
								Dry coal	......	39.4	43.3	17.26	.77	4.73	63.86	1.69	11.69	6,370	11,470
								Pure coal	......	47.7	52.3	......	.93	5.72	77.18	2.04	14.13	7,700	13,860
Do.	9272	NE.	36	22 N.	6 E.	95	3.6	As received	9.1	35.1	39.2	16.64	1.24	5.26	56.40	1.53	18.84	5,685	10,230
								Air dried	5.7	36.4	40.6	17.26	1.29	5.04	58.60	1.59	16.22	5,895	10,610
								Dry coal	......	38.6	43.1	18.30	1.36	4.67	62.13	1.68	11.86	6,255	11,260
								Pure coal	......	47.3	52.7	......	1.66	5.72	76.05	2.06	14.51	7,655	13,780
Do.	9273	NE.	36	22 N.	6 E.	94	4.0	As received	9.7	36.6	40.0	13.71	.37	5.44	59.47	1.53	19.48	5,940	10,690
								Air dried	6.0	38.1	41.6	14.28	.39	5.21	61.95	1.59	16.58	6,185	11,130
								Dry coal	......	40.5	44.3	15.19	.41	4.83	65.88	1.69	12.00	6,580	11,840
								Pure coal	......	47.8	52.2	......	.48	5.69	77.68	1.99	14.16	7,755	13,960
Do.	6487	......	36	22 N.	6 E.	96	6.3	As received	11.1	33.3	43.4	12.2	.30	......	......	......	......	5,920	10,660
								Air dried	5.2	35.5	46.3	13.0	.32	......	......	......	......	6,320	11,380
								Dry coal	......	37.5	48.8	13.7	.34	......	......	......	......	6,660	11,990
								Pure coal	......	43.4	56.6	......	.39	......	......	......	......	7,720	13,890

Ravensdale No. 1 at Ravensdale, No. 9 bed.	9277	NW.	36	22 N.	6 E.	95	2.9	As received	7.3	40.3	46.6	5.82	.63	5.87	68.28	1.76	17.64	6,875	12,370
								Air dried	4.5	41.5	48.0	5.90	.65	5.72	70.32	1.81	15.51	7,080	12,740
								Dry coal		43.5	50.2	6.28	.68	5.46	73.67	1.90	12.01	7,415	13,350
								Pure coal		46.4	53.6		.71	5.83	78.61	2.03	12.82	7,910	14,240
McKay at Ravensdale, McKay bed.	9279	SE.	36	22 N.	6 E.	97	4.9	As received	13.3	40.1	43.4	3.18	.39	6.08	64.15	1.65	24.55	6,385	11,490
								Air dried	8.0	42.1	45.7	3.34	.41	5.83	67.46	1.73	21.23	6,715	12,080
								Dry coal		46.2	50.1	3.67	.45	5.31	74.02	1.90	14.65	7,370	13,260
								Pure coal		48.0	52.0		.47	5.51	76.84	1.97	15.21	7,650	13,770
Do.	9280	NE.	1	21 N.	6 E.	97	4.7	As received	11.2	39.7	45.1	4.00	.52	6.08	65.89	1.73	21.78	6,540	11,770
								Air dried	6.8	41.7	47.3	4.21	.55	5.83	69.14	1.82	18.45	6,860	12,350
								Dry coal		44.7	50.8	4.51	.59	5.45	74.16	1.95	13.34	7,360	13,250
								Pure coal		46.8	53.2		.62	5.71	77.67	2.04	13.96	7,705	13,870
Do.	9281	NE.	1	21 N.	6 E.	97	5.0	As received	11.8	39.6	44.9	3.7	.48					6,515	11,730
								Air dried	7.1	41.7	47.3	3.9	.51					6,860	12,340
								Dry coal		44.9	50.9	4.2	.54					7,385	13,290
								Pure coal		46.8	53.2		.56					7,710	13,870
Do.	9282	NE.	1	21 N.	6 E.	97	6.8	As received	13.7	28.0	36.4	21.9	.58					4,715	8,480
								Air dried	7.4	30.0	39.1	23.5	.62					5,060	9,100
								Dry coal		32.4	42.2	25.4	.67					5,465	9,830
								Pure coal		43.5	56.5		.90					7,325	13,180
Do.	9283	NE.	1	21 N.	6 E.	97	5.5	As received	11.7	34.7	48.0	5.64	.36	6.14	64.04	1.73	22.09	6,330	11,400
								Air dried	6.6	36.7	50.7	5.97	.38	5.85	67.77	1.83	18.20	6,700	12,060
								Dry coal		39.3	54.3	6.39	.41	5.48	72.56	1.96	13.20	7,175	12,910
								Pure coal		41.9	58.1		.44	5.85	77.52	2.09	14.10	7,665	13,790
Morgan, 1 mile northwest of Black Diamond, McKay bed.	9106	SW.	11	21 N.	6 E.	98	4.6	As received	6.8	40.0	47.9	5.34	1.35	5.76	67.67	1.89	17.99	6,850	12,330
								Air dried	2.3	41.9	50.2	5.60	1.41	5.50	70.93	1.98	14.58	7,180	12,920
								Dry coal		42.9	51.4	5.73	1.45	5.37	72.57	2.03	12.85	7,345	13,220
								Pure coal		45.5	54.5		1.54	5.70	76.98	2.15	13.63	7,790	14,020
Morgan, 1 mile northwest of Black Diamond, upper McKay bed.	9108	SW.	11	21 N.	6 E.	98	5.4	As received	7.7	38.0	45.1	9.16	.44	5.48	64.07	1.38	19.47	6,485	11,670
								Air dried	2.5	40.1	47.7	9.68	.47	5.16	67.73	1.46	15.50	6,855	12,340
								Dry coal		41.2	48.9	9.93	.48	5.01	69.46	1.50	13.62	7,030	12,660
								Pure coal		45.7	54.3		.53	5.56	77.11	1.67	15.13	7,805	14,050
Black Diamond at Black Diamond, McKay bed.	9105	SE.	14	21 N.	6 E.	100	4.8	As received	7.4	39.3	49.2	4.07	1.28	5.56	68.25	1.92	18.92	6,945	12,500
								Air dried	2.7	41.3	51.7	4.28	1.34	5.28	71.69	2.02	15.39	7,295	13,130
								Dry coal		42.5	53.1	4.39	1.38	5.12	73.68	2.07	13.36	7,495	13,490
								Pure coal		44.5	55.5		1.44	5.35	77.06	2.17	13.98	7,840	14,110
Black Diamond at Black Diamond, upper McKay bed.	9114	SE.	14	21 N.	6 E.	100	6.0	As received	8.0	37.7	45.9	8.38	.45	5.60	64.79	1.69	19.09	6,520	•11,730
								Air dried	2.1	40.1	48.9	8.92	.48	5.24	68.93	1.80	14.63	6,935	12,480
								Dry coal		41.0	49.9	9.11	.49	5.12	70.41	1.84	13.03	7,085	12,750
								Pure coal		45.1	54.9		.54	5.63	77.47	2.02	14.34	7,790	14,030

Analyses of coal samples from the State of Washington—Continued.

King County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location. Quarter.	Location. Section.	Location. Township.	Location. Range.	Page.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Heat value. Calories.	Heat value. British thermal units.
Lawson, 1 mile northeast of Black Diamond, McKay bed.	9104	NW.	13	21 N.	6 E.	101	3.2	As received	4.9	41.8	48.8	4.51	0.47	5.85	72.41	1.58	15.18	7,300	13,140
								Air dried	1.8	43.2	50.3	4.66	.49	5.67	74.80	1.63	12.75	7,540	13,580
								Dry coal	....	44.0	51.3	4.74	.49	5.58	76.17	1.66	11.36	7,680	13,820
								Pure coal	....	46.2	53.8	....	.51	5.86	79.96	1.74	11.93	8,060	14,510
Lawson, 1 mile northeast of Black Diamond, upper McKay bed.	9107	NW.	13	21 N.	6 E.	101	4.2	As received	6.1	36.2	43.5	14.20	.56	5.22	62.38	1.54	16.10	6,335	11,410
								Air dried	2.0	37.8	45.4	14.82	.58	4.96	65.11	1.61	12.92	6,615	11,910
								Dry coal	....	38.6	46.3	15.12	.60	4.84	66.41	1.64	11.39	6,745	12,140
								Pure coal	....	45.4	54.6	....	.71	5.70	78.24	1.93	13.42	7,945	14,300
Surface exposure at Franklin, McKay bed.	9484	NE.	19	21 N.	7 E.	102	2.9	As received	6.1	39.2	51.3	3.44	.48	5.97	72.72	1.63	15.76	7,350	13,230
								Air dried	3.3	40.4	52.8	3.54	.49	5.82	74.89	1.68	13.58	7,570	13,630
								Dry coal	....	41.8	54.5	3.66	.51	5.63	77.45	1.74	11.01	7,830	14,090
								Pure coal	....	43.4	56.6	....	.53	5.84	80.39	1.81	11.43	8,130	14,630
Kummer at Kummer, No. 1 bed.	9113	NE.	26	21 N.	6 E.	103	12.3	As received	14.1	29.9	47.1	8.92	.43	5.80	58.39	1.32	25.14	5,795	10,430
								Air dried	2.1	34.1	53.6	10.17	.49	5.06	66.58	1.51	16.20	6,610	11,900
								Dry coal	....	34.8	54.8	10.39	.50	4.93	68.01	1.54	14.63	6,750	12,150
								Pure coal	....	38.8	61.2	....	.56	5.49	75.89	1.72	16.34	7,535	13,560
Kummer at Kummer	9115	NE.	26	21 N.	6 E.	105	9.7	As received	12.4	30.4	34.8	22.4	.59	....	....	....	....	4,730	8,510
								Air dried	2.9	33.7	38.6	24.8	.65	....	....	....	....	5,235	9,420
								Dry coal	....	34.7	39.7	25.6	.67	....	....	....	....	5,395	9,710
								Pure coal	....	46.6	53.4	....	.90	....	....	....	....	7,245	13,040
Gem at Franklin, Gem bed.	9103	NE.	19	21 N.	7 E.	105	4.9	As received	7.3	34.2	47.7	10.80	.53	5.38	63.53	1.69	18.07	6,345	11,420
								Air dried	2.5	35.9	50.2	11.36	.56	5.09	66.80	1.78	14.41	6,675	12,010
								Dry coal	....	36.9	51.5	11.65	.57	4.93	68.53	1.82	12.50	6,845	12,320
								Pure coal	....	41.8	58.2	....	.65	5.58	77.57	2.06	14.14	7,750	13,950
Surface exposure, ¾ mile southwest of Franklin, Gem (?) bed.	9487	SW.	19	21 N.	7 E.	106	7.1	As received	14.3	34.4	42.2	9.1	.57	....	....	....	....	5,710	10,280
								Air dried	7.7	37.0	45.5	9.8	.61	....	....	....	....	6,145	11,060
								Dry coal	....	40.1	49.3	10.6	.66	....	....	....	....	6,660	11,990
								Pure coal	....	44.9	55.1	....	.74	....	....	....	....	7,450	13,410

Rose-Marshall, 1 mile west of Cumberland, John Harris bed.	9293	NE.	29	21 N.	7 E.	107	2.6	As received	5.2	38.8	47.6	8.4	.47					7,025	12,650
								Air dried	2.7	39.8	48.8	8.7	.48					7,215	12,990
								Dry coal		40.9	50.2	8.9	.50					7,415	13,350
								Pure coal		44.9	55.1		.55					8,140	14,650
Do	10512	NE.	29	21 N.	7 E.	107	3.3	As received	7.2	34.4	42.4	15.99	.58	5.32	61.16	1.43	15.52	6,165	11,100
								Air dried	4.1	35.5	43.9	16.54	.60	5.12	63.25	1.48	13.01	6,375	11,480
								Dry coal		37.1	45.7	17.24	.63	4.87	65.92	1.54	9.80	6,645	11,960
								Pure coal		44.8	55.2		.76	5.88	79.65	1.86	11.85	8,030	14,450
Independent, 1 mile south of Cumberland.	9474	SW.	28	21 N.	7 E.	108	3.4	As received	6.0	29.7	40.8	23.5	.65					5,580	10,050
								Air dried	2.7	30.8	42.2	24.3	.67					5,780	10,400
								Dry coal		31.6	43.4	25.0	.69					5,940	10,700
								Pure coal		42.2	57.8		.92					7,920	14,250
Do	9286	SW.	28	21 N.	7 E.	108	3.4	As received	5.8	31.3	36.5	26.38	.47	4.80	52.77	1.30	14.28	5,295	9,530
								Air dried	2.5	32.4	37.8	27.31	.49	4.58	54.63	1.35	11.64	5,480	9,860
								Dry coal		33.3	38.7	28.02	.50	4.41	56.04	1.38	9.65	5,620	10,120
								Pure coal		46.2	53.8		.69	6.13	77.86	1.92	13.40	7,810	14,060
Sunset, 1 mile southeast of Cumberland, No. 1 bed.	9263	SE.	28	21 N.	7 E.	108	6.2	As received	12.7	31.1	43.7	12.5	.89					5,495	9,890
								Air dried	7.0	33.1	46.6	13.3	.96					5,855	10,540
								Dry coal		35.6	50.1	14.3	1.02					6,295	11,330
								Pure coal		41.5	58.5		1.19					7,345	13,220
Sunset, 1 mile southeast of Cumberland, No. 2 bed.	9264	SE.	28	21 N.	7 E.	109	2.2	As received	4.5	34.1	39.6	21.77	.77	4.91	59.23	.91	12.41	5,960	10,730
								Air dried	2.3	34.8	40.6	22.26	.79	4.77	60.56	.93	10.69	6,095	10,970
								Dry coal		35.7	41.5	22.79	.81	4.62	62.01	.95	8.82	6,240	11,230
								Pure coal		46.2	53.8		1.05	5.98	80.32	1.23	11.42	8,080	14,550
Sunset, 1 mile southeast of Cumberland, No. 3 bed.	9265	SE.	28	21 N.	7 E.	109	2.8	As received	5.6	34.4	45.0	15.01	2.41	5.13	63.79	.96	12.70	6,490	11,680
								Air dried	2.9	35.4	46.3	15.44	2.48	4.96	65.63	.99	10.50	6,680	12,020
								Dry coal		36.4	47.7	15.89	2.55	4.78	67.55	1.01	8.22	6,870	12,370
								Pure coal		43.3	56.7		3.03	5.68	80.30	1.20	9.79	8,170	14,700
Sunset, 1 mile southeast of Cumberland, No. 7 bed.	9276	SE.	28	21 N.	7 E.	109	2.6	As received	5.0	26.4	30.1	38.5	.41					4,440	7,990
								Air dried	2.4	27.1	30.9	39.6	.42					4,555	8,200
								Dry coal		27.8	31.7	40.5	.43					4,670	8,410
								Pure coal		46.8	53.2		.72					7,855	14,140
Naval at Cumberland	9287	NW.	28	21 N.	7 E.	110	2.8	As received	5.5	32.3	41.2	21.03	.69	5.01	59.49	1.64	12.14	6,010	10,820
								Air dried	2.8	33.2	42.4	21.64	.71	4.83	61.20	1.69	9.93	6,185	11,130
								Dry coal		34.2	43.6	22.24	.73	4.65	62.93	1.73	7.72	6,360	11,450
								Pure coal		43.9	56.1		.94	5.98	80.93	2.22	9.93	8,180	14,720
Do	9285	NW.	28	21 N.	7 E.	110	4.0	As received	6.2	30.0	37.5	26.3	.65					5,340	9,620
								Air dried	2.3	31.2	39.1	27.4	.68					5,565	10,020
								Dry coal		32.0	40.0	28.0	.69					5,695	10,250
								Pure coal		44.5	55.5		.95					7,915	14,250

Analyses of coal samples from the State of Washington—Continued.

King County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location. Quarter.	Section.	Township.	Range.	Page.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Volatile matter.	Fixed carbon.	Ash.	Ultimate. Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Heat value. Calories.	British thermal units.
Naval at Cumberland....	9284	NW.	28	21 N.	7 E.	110	2.7	As received....	4.8	35.6	47.4	12.16	0.52	5.35	66.81	1.65	13.51	6,775	12,190
								Air dried......	2.2	36.6	48.7	12.50	.53	5.19	68.66	1.70	11.42	6,960	12,530
								Dry coal......	....	37.4	49.8	12.77	.55	5.06	70.18	1.73	9.71	7,115	12,800
								Pure coal......	....	42.9	57.1	....	.63	5.80	80.45	1.98	11.14	8,155	14,680
Eureka, 1 mile south of Bayne.	9294	NE.	28	21 N.	7 E.	112	4.2	As received....	5.9	31.3	43.9	18.92	.47	5.08	60.35	1.13	14.05	6,075	10,940
								Air dried......	1.8	32.7	45.8	19.75	.49	4.81	63.00	1.18	10.77	6,345	11,420
								Dry coal......	....	33.3	46.6	20.11	.50	4.70	64.16	1.20	9.33	6,460	11,630
								Pure coal......	....	41.6	58.4	....	.63	5.88	80.31	1.50	11.68	8,085	14,560
Bayne at Bayne, No. 1 bed.	9112	NW.	22	21 N.	7 E.	113	7.6	As received....	8.7	30.2	42.1	19.03	.48	5.18	57.31	1.12	16.88	5,770	10,380
								Air dried......	1.2	32.6	45.6	20.59	.52	4.70	62.02	1.21	10.96	6,245	11,240
								Dry coal......	....	33.0	46.2	20.84	.53	4.62	62.75	1.23	10.03	6,315	11,370
								Pure coal......	....	41.7	58.3	....	.67	5.83	79.28	1.55	12.67	7,980	14,360
Bayne at Bayne, No. 3 bed.	9110	NW.	22	21 N.	7 E.	113	3.5	As received....	4.9	33.0	41.0	21.08	.54	5.13	59.35	1.24	12.66	5,965	10,730
								Air dried......	1.5	34.2	42.5	21.84	.56	4.92	61.50	1.29	9.89	6,180	11,120
								Dry coal......	....	34.7	43.1	22.18	.57	4.83	62.44	1.30	8.68	6,275	11,290
								Pure coal......	....	44.6	55.4	....	.73	6.21	80.23	1.67	11.16	8,060	14,510
Bayne at Bayne, No. 5 bed.	9109	NW.	22	21 N.	7 E.	113	3.6	As received....	5.1	33.8	42.7	18.43	.63	5.10	60.12	1.47	14.25	6,145	11,060
								Air dried......	1.5	35.1	44.3	19.12	.65	4.88	62.36	1.52	11.47	6,380	11,480
								Dry coal......	....	35.6	45.0	19.41	.66	4.78	63.32	1.55	10.28	6,475	11,650
								Pure coal......	....	44.2	55.8	....	.82	5.93	78.57	1.92	12.76	8,035	14,460
Do..................	9275	NW.	22	21 N.	7 E.	113	5.5	As received....	12.1	31.3	43.6	13.02	.46	5.19	56.76	1.38	23.19	5,465	9,840
								Air dried......	7.0	33.1	46.1	13.78	.49	4.85	60.07	1.46	19.35	5,785	10,410
								Dry coal......	....	35.6	49.6	14.81	.52	4.37	64.59	1.57	14.14	6,220	11,200
								Pure coal......	....	41.8	58.2	....	.61	5.13	75.81	1.84	16.61	7,300	13,140
Do..................	9268	NW.	22	21 N.	7 E.	113	4.4	As received....	7.3	33.3	41.8	17.50	.56	5.20	59.42	1.44	15.79	5,980	10,760
								Air dried......	3.0	34.9	43.7	18.40	.59	4.93	62.15	1.51	12.42	6,265	11,280
								Dry coal......	....	35.9	45.1	18.97	.60	4.74	64.10	1.55	10.04	6,450	11,610
								Pure coal......	....	44.3	55.7	....	.74	5.85	79.11	1.91	12.39	7,960	14,330

Do	9209	NW.	22	21 N.	7 E.	113	3.3	As received	5.8	37.0	48.3	8.95	.63	5.65	69.01	1.72	14.04	6,970	12,550
								Air dried	2.6	38.2	49.9	9.26	.65	5.46	71.36	1.78	11.49	7,210	12,980
								Dry coal	....	39.2	51.3	9.50	.65	5.32	73.25	1.83	9.45	7,400	13,320
								Pure coal	....	43.4	56.6	....	.72	5.88	80.94	2.02	10.44	8,175	14,720
Prospect at Bayne	9483	NW.	22	21 N.	7 E.	113	4.5	As received	7.5	23.3	35.6	33.6	1.77	....	....	....	....	4,420	7,960
								Air dried	3.1	24.4	37.3	35.2	1.85	....	....	....	....	4,630	8,330
								Dry coal	....	25.2	38.5	36.3	1.91	....	....	....	....	4,780	8,600
								Pure coal	....	39.5	60.5	....	3.00	....	....	....	....	7,505	13,500
Carbon, ½ mile northeast of Bayne, No. 1 bed.	9485	SE.	15	21 N.	7 E.	115	2.3	As received	4.2	32.4	52.3	11.13	.45	5.25	69.00	1.41	12.76	6,980	12,570
								Air dried	2.0	33.2	53.4	11.39	.46	5.11	70.62	1.44	10.98	7,145	12,860
								Dry coal	....	33.9	54.5	11.62	.47	4.99	72.05	1.47	9.40	7,290	13,120
								Pure coal	....	38.3	61.7	....	.53	5.65	81.52	1.66	10.64	8,250	14,850
Carbon, ½ mile northeast of Bayne, No. 1 bed, special sample.	9486	SE.	15	21 N.	7 E.	115	1.5	As received	3.8	33.7	53.3	9.2	.39	....	....	....	....	....	....
								Air dried	2.3	34.2	54.1	9.4	.40	....	....	....	....	....	....
								Dry coal	....	35.0	55.4	9.6	.41	....	....	....	....	....	....
								Pure coal	....	38.7	61.3	....	.45	....	....	....	....	....	....
Carbon, ½ mile northeast of Bayne, composite sample.	9492	SE.	15	21 N.	7 E.	115	1.9	As received	4.1	32.8	52.8	10.34	.45	5.33	71.51	1.56	10.81	7,100	12,780
								Air dried	2.3	33.4	53.8	10.54	.46	5.22	72.89	1.59	9.30	7,240	13,030
								Dry coal	....	34.2	55.0	10.79	.47	5.08	74.59	1.63	7.44	7,410	13,330
								Pure coal	....	38.3	61.7	....	.53	5.69	83.62	1.33	8.33	8,305	14,950
Carbon, ½ mile northeast of Bayne, No. 2 bed.	9489	SE.	15	21 N.	7 E.	115	3.1	As received	5.1	30.8	56.0	8.10	.36	5.19	72.48	1.14	12.73	7,140	12,850
								Air dried	2.1	31.8	57.7	8.36	.37	5.01	74.80	1.18	10.28	7,365	13,260
								Dry coal	....	32.5	59.0	8.54	.38	4.87	76.40	1.20	8.61	7,525	13,540
								Pure coal	....	35.5	64.5	....	.42	5.32	83.54	1.31	9.41	8,230	14,810
Prospect ¼ mile west of Bayne.	9488	NE.	21	21 N.	7 E.	116	3.5	As received	6.0	31.2	43.5	19.35	.42	4.90	59.59	1.15	14.59	5,950	10,710
								Air dried	2.6	32.3	45.1	20.05	.44	4.67	61.75	1.19	11.90	6,165	11,100
								Dry coal	....	33.2	46.2	20.59	.45	4.50	63.40	1.22	9.84	6,330	11,390
								Pure coal	....	41.8	58.2	....	.57	5.66	79.85	1.54	12.38	7,970	14,350
Occidental at Bayne, No. 1 bed.	9479	SE.	16	21 N.	7 E.	117	2.4	As received	5.1	34.4	47.6	12.93	.72	5.38	66.31	1.17	13.49	6,645	11,960
								Air dried	2.8	35.3	48.7	13.25	.74	5.24	67.94	1.20	11.63	6,810	12,260
								Dry coal	....	36.3	50.1	13.63	.76	5.07	69.90	1.22	9.42	7,005	12,610
								Pure coal	....	42.0	58.0	....	.88	5.86	80.93	1.41	10.92	8,110	14,600
Occidental at Bayne, No. 2 bed.	9480	SE.	16	21 N.	7 E.	117	2.5	As received	5.4	33.0	47.1	14.51	.70	5.20	64.12	1.28	14.19	6,440	11,590
								Air dried	2.9	33.9	48.3	14.88	.72	5.05	65.77	1.31	12.27	6,605	11,890
								Dry coal	....	34.9	49.8	15.33	.74	4.87	67.74	1.35	9.97	6,800	12,240
								Pure coal	....	41.2	58.8	....	.87	5.75	80.01	1.59	11.78	8,035	14,460
Occidental at Bayne, No. 3 bed.	9478	SE.	16	21 N.	7 E.	117	2.1	As received	4.8	34.3	48.5	12.42	1.12	5.60	66.87	1.12	12.87	6,780	12,200
								Air dried	2.7	35.1	49.5	12.69	1.14	5.49	68.30	1.14	11.24	6,925	12,460
								Dry coal	....	36.1	50.9	13.04	1.18	5.32	70.22	1.18	9.06	7,120	12,820
								Pure coal	....	41.5	58.5	....	1.36	6.12	80.75	1.36	10.41	8,190	14,740

Analyses of coal samples from the State of Washington—Continued.

King County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location: Quarter.	Location: Section.	Location: Township.	Location: Range.	Page.	Air-drying loss.	Form of analysis.	Proximate: Moisture.	Proximate: Volatile matter.	Proximate: Fixed carbon.	Proximate: Ash.	Ultimate: Sulphur.	Ultimate: Hydrogen.	Ultimate: Carbon.	Ultimate: Nitrogen.	Ultimate: Oxygen.	Heat value: Calories.	Heat value: British thermal units.
Occidental at Bayne, No. 3 bed.	9475	SE.	16	21 N.	7 E.	117	2.1	As received	5.1	34.4	48.9	11.65	1.18	5.22	66.72	1.08	14.15	6,705	12,070
								Air dried	3.0	35.1	50.0	11.90	1.21	5.10	68.15	1.10	12.54	6,850	12,330
								Dry coal		36.2	51.5	12.27	1.24	4.90	70.28	1.14	10.17	7,060	12,710
								Pure coal		41.3	58.7		1.41	5.59	80.11	1.30	11.59	8,050	14,490
Occidental at Bayne, No. 6 bed.	9481	SE.	16	21 N.	7 E.	117	2.8	As received	5.5	31.8	40.9	21.80	.50	4.91	57.00	1.30	14.49	5,785	10,410
								Air dried	2.9	32.7	42.0	22.43	.52	4.73	58.64	1.34	12.34	5,950	10,710
								Dry coal		33.7	43.2	23.08	.53	4.54	60.35	1.38	10.12	6,120	11,020
								Pure coal		43.8	56.2		.69	5.90	78.46	1.79	13.16	7,960	14,320
Occidental at Bayne, No. 14 bed.	9477	SE.	16	21 N.	7 E.	117	1.8	As received	4.2	33.1	45.5	17.2	.58						
								Air dried	2.4	33.8	46.3	17.5	.59						
								Dry coal		34.6	47.4	18.0	.61						
								Pure coal		42.1	57.9		.74						
Do.	9476	SE.	16	21 N.	7 E.	117	1.6	As received	4.1	36.7	52.6	6.6	.51						
								Air dried	2.5	37.3	53.5	6.7	.52						
								Dry coal		38.3	54.8	6.9	.57						
								Pure coal		41.1	58.9		.57						
Occidental at Bayne, composite sample.	9491	SE.	16	21 N.	7 E.	119	1.7	As received	4.0	35.2	48.7	12.09	.49	5.55	67.50	1.70	12.67	6,855	12,340
								Air dried	2.3	35.8	49.6	12.30	.50	5.45	68.67	1.73	11.35	6,975	12,560
								Dry coal		36.6	50.8	12.59	.51	5.32	70.29	1.77	9.52	7,140	12,850
								Pure coal		41.9	58.1		.58	6.09	80.41	2.02	10.90	8,170	14,700
Big Six, 1½ miles east of Bayne, Pocahontas bed.	9278	NE.	23	21 N.	7 E.	119	3.1	As received	4.6	31.0	52.2	12.24	.73	5.27	70.07	1.05	10.64	7,075	12,730
								Air dried	1.5	32.0	53.9	12.63	.75	5.09	72.31	1.08	8.14	7,300	13,140
								Dry coal		32.5	54.7	12.83	.76	4.99	73.43	1.10	6.89	7,415	13,340
								Pure coal		37.3	62.7		.87	5.72	84.24	1.26	7.91	8,505	15,310
Prospect at Palmer Junction.	9288	NE.	14	21 N.	7 E.	120	2.5	As received	4.4	25.0	37.3	33.3	.58					4,975	8,950
								Air dried	2.0	25.6	38.2	34.2	.59					5,100	9,180
								Dry coal		26.1	39.0	34.9	.61					5,200	9,300
								Pure coal		40.1	59.9		.94					7,990	14,380

Do.	9482	NE.	14	21 N.	7 E.	120	2.9	As received	4.8	23.7	39.1	32.4	.66					5,040	9,070
								Air dried	1.9	24.4	40.3	33.4	.68					5,190	9,340
								Dry coal		24.9	41.1	34.0	.69					5,290	9,520
								Pure coal		37.7	62.3		1.05					8,020	14,430
Prospect shaft 3½ miles east of Ravensdale.	9292	SE.	28	22 N.	7 E.	122	5.7	As received	10.5	35.2	42.4	11.93	.35	5.60	59.74	.88	21.50	5,945	10,700
								Air dried	5.0	37.3	45.0	12.65	.37	5.27	63.35	.93	17.43	6,305	11,350
								Dry coal		39.3	47.4	13.32	.39	4.96	66.71	.98	13.64	6,640	11,950
								Pure coal		45.3	54.7		.45	5.72	76.96	1.13	15.74	7,660	13,790
Prospect near Barneston.	9111	NW.	12	22 N.	7 E.	123	12.6	As received	14.0	5.5	51.7	28.8	.43					4,450	8,010
								Air dried	1.7	6.2	59.1	33.0	.49					5,095	9,170
								Dry coal		6.4	60.1	33.5	.50					5,180	9,320
								Pure coal		9.5	90.5		.75					7,790	14,030
Denny-Renton at Taylor, No. 2 bed.	9173	SW.	3	22 N.	7 E.	124	4.0	As received	6.4	36.7	41.4	15.5	1.33					6,190	11,140
								Air dried	2.5	38.2	43.2	16.1	1.39					6,450	11,610
								Dry coal		39.2	44.3	16.5	1.42					6,610	11,900
								Pure coal		46.9	53.1		1.70					7,920	14,260
Denny-Renton at Taylor, No. 3 bed.	9176	SW.	3	22 N.	7 E.	124	2.6	As received	5.0	36.1	34.0	24.9	1.92					5,555	10,000
								Air dried	2.4	37.1	34.9	25.6	1.97					5,705	10,270
								Dry coal		38.0	35.8	26.2	2.02					5,845	10,520
								Pure coal		51.5	48.5		2.74					7,920	14,260
Denny-Renton at Taylor, No. 4 bed.	9172	SE.	3	22 N.	7 E.	124	2.6	As received	4.8	36.4	48.7	10.05	.81	5.37	68.09	1.35	14.33	6,890	12,410
								Air dried	2.2	37.4	50.1	10.32	.83	5.22	69.91	1.39	12.33	7,075	12,740
								Dry coal		38.3	51.2	10.55	.85	5.09	71.49	1.42	10.60	7,235	13,030
								Pure coal		42.8	57.2		.95	5.69	79.92	1.59	11.85	8,090	14,560
Denny-Renton at Taylor, No. 5 bed.	9174	SE.	3	22 N.	7 E.	124	2.3	As received	4.3	35.6	45.2	14.85	.74	5.20	65.14	1.60	12.47	6,595	11,870
								Air dried	2.1	36.4	46.3	15.20	.76	5.06	66.67	1.64	10.67	6,750	12,150
								Dry coal		37.2	47.3	15.52	.77	4.93	68.06	1.67	9.05	6,890	12,400
								Pure coal		44.0	56.0		.91	5.84	80.56	1.98	10.71	8,155	14,680
Do.	520-D	SW.	3	22 N.	7 E.	124	3.5	As received	6.1	40.0	37.8	16.1	1.01						
								Air dried	2.8	41.4	39.1	16.7	1.05						
								Dry coal		42.6	40.3	17.1	1.08						
								Pure coal		51.4	48.6		1.28						
Do.	518-D	SW.	3	22 N.	7 E.	124	2.2	As received	4.1	35.9	43.5	16.5	.54					6,420	11,560
								Air dried	1.9	36.7	44.5	16.9	.55					6,565	11,820
								Dry coal		37.4	45.4	17.2	.55					6,695	12,050
								Pure coal		45.2	54.8		.66					8,085	14,550
Denny-Renton at Taylor, No. 4 bed.	519-D	SE.	3	22 N.	7 E.	124	3.3	As received	5.4	37.7	48.3	8.6	.63					6,860	12,340
								Air dried	2.1	39.0	50.0	8.9	.65					7,095	12,770
								Dry coal		39.8	51.1	9.1	.67					7,245	13,040
								Pure coal		43.8	56.2		.74					7,970	14,350

Analyses of coal samples from the State of Washington—Continued.

King County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location: Quarter.	Location: Section.	Location: Township.	Location: Range.	Page.	Air-drying loss.	Form of analysis.	Proximate: Moisture.	Proximate: Volatile matter.	Proximate: Fixed carbon.	Proximate: Ash.	Ultimate: Sulphur.	Ultimate: Hydrogen.	Ultimate: Carbon.	Ultimate: Nitrogen.	Ultimate: Oxygen.	Heat value: Calories.	Heat value: British thermal units.
Denny-Renton at Taylor, No. 6 bed.	9175	SE.	3	22 N.	7 E.	124	3.1	As received	5.6	35.9	44.1	14.38	0.94	5.18	63.91	1.26	14.33	6,415	11,550
								Air dried	2.5	37.1	45.6	14.84	.97	4.99	65.95	1.30	11.96	6,620	11,920
								Dry coal		38.1	46.7	15.23	1.00	4.83	67.67	1.33	9.94	6,795	12,230
								Pure coal		44.9	55.1		1.18	5.70	79.83	1.57	11.72	8,015	14,430
Denny-Renton at Taylor, No. 5 bed.	6485		3	22 N.	7 E.	125	3.3	As received	5.4	24.5	31.6	38.5	.51					4,255	7,660
								Air dried	2.2	25.3	32.7	39.8	.53					4,400	7,920
								Dry coal		25.9	33.4	40.7	.54					4,495	8,100
								Pure coal		43.7	56.3		.91					7,585	13,660
Denny-Renton at Taylor, run-of-mine coal, No. 4 bed.	585-D	SE.	3	22 N.	7 E.	125	2.6	As received	6.2	34.2	41.4	18.23	.69	4.95	60.12	1.41	14.60	6,050	10,890
								Air dried	3.7	35.1	42.5	18.72	.71	4.78	61.72	1.45	12.62	6,210	11,180
								Dry coal		36.5	44.1	19.44	.74	4.54	64.09	1.50	9.69	6,450	11,610
								Pure coal		45.3	54.7		.92	5.63	79.56	1.86	12.08	8,005	14,410
Denny-Renton at Taylor, run-of-mine coal, No. 5 bed.	586-D	SW.	3	22 N.	7 E.	125	2.3	As received	5.3	34.2	37.8	22.67	.77	4.72	56.98	1.37	13.49	5,730	10,310
								Air dried	3.1	35.0	38.7	23.20	.79	4.57	58.32	1.40	11.72	5,860	10,550
								Dry coal		36.1	39.9	23.95	.81	4.36	60.20	1.45	9.23	6,050	10,890
								Pure coal		47.5	52.5		1.06	5.73	79.16	1.91	12.14	7,960	14,330
Prospect 6 miles southeast of Issaquah.	9290	SW.	12	23 N.	6 E.	126	8.9	As received	11.4	27.4	50.5	10.7	.23					6,330	11,390
								Air dried	2.7	30.1	55.4	11.8	.25					6,950	12,510
								Dry coal		30.9	57.0	12.1	.26					7,145	12,860
								Pure coal		35.2	64.8		.30					8,130	14,630
Do.	9289	SW.	12	23 N.	6 E.	126	8.5	As received	12.5	28.0	45.6	13.9	2.37					5,700	10,260
								Air dried	4.4	30.6	49.8	15.2	2.59					6,230	11,220
								Dry coal		32.0	52.1	15.9	2.71					6,520	11,740
								Pure coal		38.1	61.9		3.22					7,750	13,950
Prospect 1 mile southwest of Preston.	8546	SE.	31	24 N.	7 E.	127	4.0	As received	5.5	7.3	30.5	56.7	3.30					2,710	4,880
								Air dried	1.6	7.6	31.8	59.0	3.44					2,825	5,080
								Dry coal		7.7	32.3	60.0	3.49					2,870	5,160
								Pure coal		19.3	80.7		8.72					7,165	12,890

Niblock, 1¼ miles southwest of Snoqualmie, No. 3 bed.	10031	SE.	1	23 N.	7 E.	128	7.3	As received	8.2	27.2	53.9	10.69	.47	5.22	69.64	1.84	12.14	6,910	12,440
								Air dried	1.0	29.3	58.2	11.53	.51	4.76	75.12	1.98	6.10	7,455	13,420
								Dry coal		29.6	58.7	11.65	.51	4.69	75.89	2.01	5.25	7,530	13,500
								Pure coal		33.5	66.5		.58	5.31	85.90	2.28	5.93	8,525	15,340
Niblock, 1¼ miles southwest of Snoqualmie, No. 4 bed.	10032	SE.	1	23 N.	7 E.	128	4.1	As received	6.1	22.7	58.8	12.4	.88					5,950	10,710
								Air dried	2.1	23.7	61.3	12.9	.92					6,205	11,170
								Dry coal		24.2	62.6	13.2	.94					6,335	11,400
								Pure coal		27.8	72.2		1.08					7,300	13,140
Niblock, 1¼ miles southwest of Snoqualmie, No. 5 bed.	10033	NW.	1	23 N.	7 E.	128	3.7	As received	4.8	27.3	43.6	24.34	1.48	4.92	57.86	1.38	10.02	5,875	10,580
								Air dried	1.2	28.3	45.2	25.28	1.54	4.68	60.08	1.43	6.99	6,100	10,980
								Dry coal		28.6	45.8	25.58	1.56	4.60	60.81	1.45	6.00	6,175	11,120
								Pure coal		38.5	61.5		2.10	6.18	81.71	1.95	8.06	8,300	14,940
Kittitas County.																			
Prospect, 1¼ miles northwest of Beekman.	9404	NW.	2	20 N.	14 E.	131	4.1	As received	5.3	27.5	42.6	24.6	0.38					5,860	10,550
								Air dried	1.2	28.7	44.4	25.7	.40					6,110	11,000
								Dry coal		29.1	44.9	26.0	.40					6,185	11,130
								Pure coal		39.3	60.7		.54					8,355	15,040
Lakedale, 1 mile northwest of Beekman.	9405	SW.	1	20 N.	14 E.	[illegible]	2.5	As received	4.5	29.5	44.5	21.48	.35	5.02	61.45	1.18	10.52	6,235	11,220
								Air dried	2.0	30.3	45.7	22.03	.36	4.86	63.03	1.21	8.51	6,395	11,510
								Dry coal		30.9	46.6	22.48	.37	4.74	64.31	1.23	6.87	6,525	11,7[illegible]0
								Pure coal		39.9	60.1		.48	6.11	82.96	1.59	8.86	8,415	15,1[illegible]0
Beekman at Beekman, Roslyn bed.	9411	NW.	12	20 N.	14 E.	133	2.4	As received	3.7	35.1	50.5	10.7	.33						
								Air dried	1.3	36.0	51.7	11.0	.33						
								Dry coal		36.5	52.4	11.1	.33						
								Pure coal		41.0	59.0		.37						
Do.	9412	SE.	12	20 N.	14 E.	133	1.8	As received	3.5	34.6	50.2	11.7	.38						
								Air dried	1.8	35.2	51.1	11.9	.39						
								Dry coal		35.9	52.0	12.1	.39						
								Pure coal		40.8	59.2		.44						
Do.	9413	SE.	12	20 N.	14 E.	133	1.8	As received	3.4	35.5	49.8	11.3	.37						
								Air dried	1.6	36.2	50.7	11.5	.38						
								Dry coal		36.8	51.5	11.7	.38						
								Pure coal		41.6	58.4		.43						
Do.	9414	NW.	12	20 N.	14 E.	133	1.0	As received	2.5	34.9	50.0	12.6	.33						
								Air dried	1.5	35.2	50.5	12.8	.33						
								Dry coal		35.8	51.3	12.9	.34						
								Pure coal		41.1	58.9		.39						
Do.	9415	SW.	12	20 N.	14 E.	133	.8	As received	2.6	34.7	48.9	13.8	.34						
								Air dried	1.8	35.0	49.3	13.9	.34						
								Dry coal		35.6	50.2	14.2	.35						
								Pure coal		41.5	58.5		.41						

Analyses of coal samples from the State of Washington—Continued.

Kittitas County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location.				Page.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
		Quarter.	Section.	Township.	Range.				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Beekman at Beekman, Roslyn bed, car sample.	9410	SW.	12	20 N.	14 E.	134	2.7	As received	4.4	33.2	49.5	12.94	0.35	5.46	69.83	1.56	9.86	6,960	12,520
								Air dried	1.7	34.1	50.9	13.30	.36	5.30	71.77	1.60	7.67	7,150	12,870
								Dry coal	......	34.7	51.8	13.53	.37	5.20	73.02	1.63	6.25	7,275	13,100
								Pure coal	......	40.2	59.8	......	.43	6.01	84.45	1.89	7.22	8,415	15,150
Beekman at Beekman, composite sample.	9459	......	12	20 N.	14 E.	134	1.8	As received	3.3	34.1	50.5	12.15	.35	5.61	70.67	1.65	9.57	7,175	12,910
								Air dried	1.5	34.7	51.4	12.37	.36	5.51	71.97	1.68	8.11	7,305	13,150
								Dry coal	......	35.2	52.2	12.57	.36	5.42	73.10	1.71	6.84	7,420	13,360
								Pure coal	......	40.3	59.7	......	.41	6.20	83.60	1.96	7.83	8,485	15,280
Beekman at Beekman, Roslyn bed.	550-D	......	12	20 N.	14 E.	133	1.9	As received	3.5	38.4	48.3	9.8	.41	......	......	......	......	7,345	13,220
								Air dried	1.6	39.2	49.2	10.0	.42	......	......	......	......	7,490	13,480
								Dry coal	......	39.8	50.0	10.2	.43	......	......	......	......	7,610	13,700
								Pure coal	......	44.3	55.7	......	.48	......	......	......	......	8,470	15,250
Do	551-D	......	12	20 N.	14 E.	133	7.5	As received	9.0	36.2	46.1	8.7	.35	......	......	......	......	......	......
								Air dried	1.5	39.2	49.8	9.5	.38	......	......	......	......	......	......
								Dry coal	......	39.8	50.6	9.6	.39	......	......	......	......	......	......
								Pure coal	......	44.0	56.0	......	.43	......	......	......	......	......	......
Beekman at Beekman, Roslyn bed, car sample.	693-D	......	12	20 N.	14 E.	134	5.8	As received	7.8	33.1	44.9	14.18	.45	5.48	64.67	1.41	13.81	6,615	11,900
								Air dried	2.2	35.1	47.7	15.05	.48	5.14	68.65	1.50	9.18	7,020	12,630
								Dry coal	......	35.9	48.7	15.38	.49	5.00	70.16	1.53	7.44	7,175	12,910
								Pure coal	......	42.4	57.6	......	.58	5.91	82.91	1.81	8.79	8,480	15,260
Busy Bee, 2½ miles northwest of Roslyn, Roslyn bed.	9406	NE.	12	20 N.	14 E.	135	1.4	As received	3.3	36.2	51.6	8.9	.41	......	......	......	......	7,430	13,370
								Air dried	1.9	36.7	52.3	9.1	.42	......	......	......	......	7,535	13,560
								Dry coal	......	37.5	53.3	9.2	.42	......	......	......	......	7,685	13,830
								Pure coal	......	41.3	58.7	......	.46	......	......	......	......	8,465	15,240
Patrick-McKay, 3½ miles northwest of Roslyn, Rosyln bed.	9418	SW.	6	20 N.	15 E.	136	1.1	As received	3.3	36.0	48.8	11.9	.37	......	......	......	......	......	......
								Air dried	3.2	36.3	49.4	12.1	.37	......	......	......	......	......	......
								Dry coal	......	37.2	50.5	12.3	.38	......	......	......	......	......	......
								Pure coal	......	42.4	57.6	......	.43	......	......	......	......	......	......

Do	9416	SW.	6	20 N.	15 E.	136	1.1	As received	3.0	36.9	49.6	10.5	.38							
								Air dried	1.9	37.4	50.1	10.6	.39							
								Dry coal		38.1	51.1	10.8	.39							
								Pure coal		42.7	57.3		.44							
Do	9417	SE.	6	20 N.	15 E.	136	1.1	As received	3.0	36.2	49.3	11.5	.38							
								Air dried	1.9	36.6	49.9	11.6	.38							
								Dry coal		37.3	50.8	11.9	.39							
								Pure coal		42.3	57.7		.44							
Patrick-McKay, 3½ miles northwest of Roslyn, composite sample.	9460		6	20 N.	15 E.	137	1.1	As received	3.1	35.6	50.0	11.27	.41	5.63	70.18	1.44	11.07	7,140	12,850
								Air dried	2.0	36.0	50.6	11.40	.41	5.57	70.96	1.46	10.20	7,215	12,990
								Dry coal		36.7	51.7	11.63	.42	5.46	72.41	1.49	8.59	7,365	13,260
								Pure coal		41.6	58.4		.48	6.18	81.94	1.69	9.71	8,335	15,000
Patrick-McKay, 3½ miles northwest of Roslyn, lower bed.	9407	NW.	6	20 N.	15 E.	137	2.5	As received	4.1	33.0	46.5	16.43	.80	5.29	65.09	1.21	11.18	6,575	11,830
								Air dried	1.6	33.9	47.7	16.85	.81	5.14	66.76	1.25	9.19	6,745	12,140
								Dry coal		34.4	48.5	17.13	.83	5.04	67.87	1.26	7.87	6,855	12,340
								Pure coal		41.5	58.5		1.00	6.07	81.90	1.52	9.51	8,270	14,890
Roslyn No. 3 at Ronald, Roslyn bed.	9428	NW.	7	20 N.	15 E.	138	1.3	As received	3.4	36.4	49.5	10.7	.40						
								Air dried	2.2	36.8	50.2	10.8	.41						
								Dry coal		37.6	51.3	11.1	.41						
								Pure coal		42.3	57.7		.46						
Do	9429	NE.	7	20 N.	15 E.	138	1.1	As received	3.2	36.5	49.2	11.1	.37						
								Air dried	2.1	36.9	49.8	11.2	.37						
								Dry coal		37.7	50.8	11.5	.38						
								Pure coal		42.6	57.4		.43						
Do	9432	NW.	7	20 N.	15 E.	138	1.0	As received	3.2	36.4	49.8	10.6	.33						
								Air dired	2.2	36.8	50.3	10.7	.33						
								Dry coal		37.6	51.4	11.0	.34						
								Pure coal		42.2	57.8		.38						
Do	9431	SE.	7	20 N.	15 E.	138	1.0	As received	3.2	36.1	46.7	14.0	.69						
								Air dried	2.2	36.4	47.2	14.2	.39						
								Dry coal		37.3	48.2	14.5	.40						
								Pure coal		43.6	56.4		.47						
Do	9430	SW.	7	20 N.	15 E.	138	1.1	As received	3.3	35.2	51.1	10.4	.33						
								Air dried	2.2	35.6	51.7	10.5	.33						
								Dry coal		36.4	52.9	10.7	.34						
								Pure coal		40.8	59.2		.38						
Roslyn No. 3 at Ronald, composite sample.	9463		7	20 N.	15 E.	139	1.1	As received	3.1	35.6	49.9	11.37	.40	5.53	70.29	1.54	10.87	7,145	12,860
								Air dried	2.0	36.0	50.5	11.50	.40	5.47	71.07	1.56	10.00	7,225	13,010
								Dry coal		36.8	51.5	11.73	.41	5.36	72.53	1.59	8.38	7,375	13,270
								Pure coal		41.6	58.4		.47	6.07	82.17	1.80	9.49	8,350	15,030

Analyses of coal samples from the State of Washington—Continued.

Kittitas County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location.				Page.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
		Quarter.	Section.	Township.	Range.				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Roslyn No. 2 slope at Roslyn, Roslyn bed.	9433	SE.	18	20 N.	15 E.	139	0.9	As received	2.9	35.8	48.7	12.6	.37						
								Air dried	2.0	36.1	49.2	12.7	.37						
								Dry coal		36.8	50.2	13.0	.38						
								Pure coal		42.3	57.7		.44						
Do	9434	NW.	18	20 N.	15 E.	139	1.8	As received	3.4	34.6	50.5	11.5	.36						
								Air dried	1.6	35.2	51.5	11.7	.37						
								Dry coal		35.8	52.3	11.9	.37						
								Pure coal		40.7	59.3		.42						
Do	9435	SW.	17	20 N.	15 E.	139	1.8	As received	3.3	35.9	48.5	12.3	.37						
								Air dried	1.6	36.6	49.3	12.5	.38						
								Dry coal		37.2	50.1	12.7	.38						
								Pure coal		42.6	57.4		.44						
Do	9436	SE.	18	20 N.	15 E.	139	1.1	As received	3.1	35.9	47.7	13.3	.31						
								Air dried	2.0	36.3	48.2	13.5	.31						
								Dry coal		37.1	49.2	13.7	.32						
								Pure coal		43.0	57.0		.37						
Roslyn No. 2 slope at Roslyn, composite sample.	9464			20 N.	15 E.	140	1.4	As received	3.1	35.6	48.8	12.47	.35	5.47	69.08	1.53	11.10	7,025	12,640
								Air dried	1.8	36.1	49.5	12.65	.35	5.39	70.06	1.55	10.00	7,125	12,820
								Dry coal		36.7	50.4	12.88	.36	5.29	71.33	1.58	8.56	7,255	13,060
								Pure coal		42.2	57.8		.41	6.07	81.87	1.81	9.84	8,325	14,980
Roslyn No. 2 at Roslyn, Roslyn bed.	9442	SW.	9	20 N.	15 E.	141	1.9	As received	4.5	37.0	46.5	12.0	.42						
								Air dried	2.6	37.7	47.5	12.2	.43						
								Dry coal		38.7	48.7	12.6	.44						
								Pure coal		44.3	55.7		.50						
Do	9443	NE.	8	20 N.	15 E.	141	1.8	As received	4.4	35.4	47.2	13.0	.41						
								Air dried	2.7	36.1	48.0	13.2	.42						
								Dry coal		37.1	49.3	13.6	.43						
								Pure coal		42.9	57.1		.50						

Do	9444	SE.	9	20 N.	15 E.	141	2.2	As received	5.4	36.5	46.2	11.9	.39						
								Air dried	3.3	37.3	47.2	12.2	.40						
								Dry coal		38.6	48.8	12.6	.41						
								Pure coal		44.2	55.8		.47						
Roslyn No. 2 at Roslyn, composite sample.	9468			20 N.	15 E.	141	2.0	As received	4.7	36.0	46.8	12.46	.38	5.87	66.86	1.34	13.09	6,800	12,240
								Air dried	2.7	36.8	47.8	12.71	.39	5.77	68.22	1.37	11.54	6,940	12,490
								Dry coal		37.8	49.1	13.07	.40	5.61	70.13	1.41	9.38	7,135	12,840
								Pure coal		43.4	56.6		.46	6.45	80.67	1.62	10.80	8,205	14,770
Roslyn No. 2 at Roslyn, Roslyn bed.	2457			20 N.	15 E.	141	.9	As received	3.4	36.1	46.6	13.9	.36						
								Air dried	2.5	36.5	47.0	14.0	.36						
								Dry coal		37.4	48.2	14.4	.37						
								Pure coal		43.7	56.3		.43						
Roslyn No. 2 at Roslyn, lump coal.	3098					141	1.3	As received	3.1	36.5	48.1	12.28	.38	5.15	69.35	1.24	11.62	6,990	12,590
								Air dried	1.9	37.0	48.7	12.42	.38	5.08	70.26	1.26	10.60	7,085	12,750
								Dry coal		37.7	49.6	12.66	.39	4.96	71.62	1.28	9.09	7,220	13,000
								Pure coal		43.2	56.8		.45	5.68	81.99	1.47	10.41	8,270	14,880
A. & E. mine, 1 mile northeast of Roslyn, Roslyn bed.	9402	SW.	10	20 N.	15 E.	142	2.5	As received	5.7	36.9	44.7	12.69	.45	5.47	65.55	1.28	14.56	6,630	11,930
								Air dried	3.3	37.9	45.8	13.02	.46	5.32	67.23	1.31	12.66	6,800	12,240
								Dry coal		39.2	47.3	13.46	.48	5.13	69.51	1.36	10.06	7,030	12,650
								Pure coal		45.3	54.7		.55	5.93	80.32	1.57	11.63	8,125	14,620
Roslyn No. 6 at Roslyn, Roslyn bed.	9439	NE.	16	20 N.	15 E.	143	1.9	As received	4.4	36.7	46.4	12.5	.41						
								Air dried	2.6	37.4	47.3	12.7	.42						
								Dry coal		38.4	48.6	13.0	.43						
								Pure coal		44.2	55.8		.49						
Do	9441	NE.	16	20 N.	15 E.	143	1.8	As received	4.5	36.4	46.5	12.6	.42						
								Air dried	2.7	37.1	47.4	12.8	.43						
								Dry coal		38.1	48.7	13.2	.44						
								Pure coal		43.9	56.1		.51						
Do	9440	NE.	16	20 N.	15 E.	143	2.1	As received	4.8	37.3	45.6	12.3	.38						
								Air dried	2.8	38.0	46.6	12.6	.39						
								Dry coal		39.1	47.9	13.0	.40						
								Pure coal		45.0	55.0		.46						
Roslyn No. 6 at Roslyn, composite sample.	9466		16	20 N.	15 E.	143	1.9	As received	4.6	36.1	46.8	12.53	.40	5.37	67.42	1.30	12.98	6,755	12,150
								Air dried	2.8	36.8	47.6	12.77	.40	5.26	68.73	1.33	11.51	6,885	12,390
								Dry coal		37.9	49.0	13.14	.42	5.09	70.71	1.36	9.28	7,085	12,750
								Pure coal		43.6	56.4		.48	5.86	81.41	1.57	10.68	8,155	14,680
Roslyn No. 4 at Roslyn, Roslyn bed.	9438	NW.	20	20 N.	15 E.	144	2.2	As received	3.7	33.8	48.0	14.5	.35						
								Air dried	1.6	34.6	49.0	14.8	.36						
								Dry coal		35.1	49.8	15.1	.36						
								Pure coal		41.3	58.7		.42						

Analyses of coal samples from the State of Washington—Continued.

Kittitas County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location. Quarter.	Location. Section.	Location. Township.	Location. Range.	Page.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Heat value. Calories.	Heat value. British thermal units.
Roslyn No. 4 at Roslyn, Roslyn bed.	9437	NE.	20	20 N.	15 E.	144	1.4	As received	3.7	35.8	48.2	12.3	0.37						
								Air dried	2.3	36.4	48.9	12.4	.38						
								Dry coal		37.2	50.0	12.8	.38						
								Pure coal		42.7	57.3		.44						
Roslyn No. 4 at Roslyn, composite sample.	9465		20	20 N.	15 E.	144	1.8	As received	3.7	34.3	48.6	13.40	.36	5.43	67.57	1.28	11.96	6,805	12,250
								Air dried	1.9	35.0	49.5	13.65	.37	5.33	68.81	1.30	10.54	6,935	12,480
								Dry coal		35.6	50.5	13.91	.37	5.21	70.15	1.33	9.03	7,065	12,720
								Pure coal		41.4	58.6		.43	6.05	81.49	1.54	10.49	8,210	14,780
Roslyn No. 4 at Roslyn, Roslyn bed.	2458		17	20 N.	15 E.	144	1.3	As received	3.4	37.3	48.9	10.4	.33					7,135	12,850
								Air dried	2.1	37.9	49.5	10.5	.33					7,230	13,020
								Dry coal		38.6	50.6	10.8	.34					7,385	13,300
								Pure coal		43.3	56.7		.38					8,280	14,900
Roslyn No. 5, 1¼ miles southeast of Roslyn, Roslyn bed.	9427	SW.	16	20 N.	15 E.	145	1.9	As received	4.7	36.9	47.4	11.0	.35						
								Air dried	2.9	37.6	48.3	11.2	.36						
								Dry coal		38.7	49.7	11.6	.37						
								Pure coal		43.8	56.2		.42						
Do	9423	SW.	22	20 N.	15 E.	145	1.6	As received	5.4	35.7	46.9	12.0	.36						
								Air dried	3.9	36.3	47.7	12.1	.37						
								Dry coal		37.7	49.6	12.7	.38						
								Pure coal		43.2	56.8		.44						
Do	9424	NW.	21	20 N.	15 E.	145	1.4	As received	4.2	35.3	47.2	13.3	.37						
								Air dried	2.9	35.8	47.8	13.5	.38						
								Dry coal		36.9	49.2	13.9	.39						
								Pure coal		42.8	57.2		.45						
Do	9426	SW.	22	20 N.	15 E.	145	1.7	As received	5.2	36.6	46.4	11.8	.38						
								Air dried	3.6	37.2	47.2	12.0	.39						
								Dry coal		38.6	49.0	12.4	.40						
								Pure coal		44.1	55.9		.46						

Do	9425	SE.	21	20 N.	15 E.	145	1.5	As received	5.0	34.9	49.6	10.5	.39	....	....	....	....	....	....
								Air dried	3.5	35.5	50.3	10.7	.40	....	....	....	....	....	....
								Dry coal	....	36.8	52.1	11.1	.41	....	....	....	....	....	....
								Pure coal	....	41.3	58.7	....	.46	....	....	....	....	....	....
Roslyn No. 5, 1¼ miles southeast of Roslyn, composite sample.	9462	....	....	20 N.	15 E.	146	1.6	As received	4.9	36.0	47.3	11.77	.40	5.54	67.68	1.27	13.34	6,810	12,250
								Air dried	3.4	36.5	48.1	11.97	.41	5.45	68.78	1.29	12.10	6,920	12,450
								Dry coal	....	37.8	49.8	12.38	.42	5.25	71.21	1.34	9.40	7,165	12,890
								Pure coal	....	43.2	56.8	....	.48	5.99	81.27	1.53	10.73	8,175	14,710
Roslyn No. 7, ½ mile northeast of Clealum, Roslyn bed.	9422	SE.	22	20 N.	15 E.	147	1.5	As received	5.5	36.2	46.5	11.8	.33	....	....	....	....	....	....
								Air dried	4.1	36.8	47.2	11.9	.33	....	....	....	....	....	....
								Dry coal	....	38.3	49.2	12.5	.35	....	....	....	....	....	....
								Pure coal	....	43.8	56.2	....	.40	....	....	....	....	....	....
Do	9421	NW.	26	20 N.	15 E.	147	2.0	As received	7.0	34.5	44.9	13.6	.37	....	....	....	....	....	....
								Air dried	5.1	35.2	45.8	13.9	.38	....	....	....	....	....	....
								Dry coal	....	37.1	48.3	14.6	.40	....	....	....	....	....	....
								Pure coal	....	43.5	56.5	....	.47	....	....	....	....	....	....
Do	9420	SE.	22	20 N.	15 E.	147	2.4	As received	6.3	35.8	46.3	11.6	.35	....	....	....	....	....	....
								Air dried	4.0	36.6	47.5	11.9	.36	....	....	....	....	....	....
								Dry coal	....	38.2	49.4	12.4	.37	....	....	....	....	....	....
								Pure coal	....	43.6	56.4	....	.42	....	....	....	....	....	....
Do	9419	NE.	27	20 N.	15 E.	147	2.0	As received	6.0	34.9	47.2	11.9	.34	....	....	....	....	....	....
								Air dried	4.1	35.7	48.1	12.1	.35	....	....	....	....	....	....
								Dry coal	....	37.2	50.2	12.6	.36	....	....	....	....	....	....
								Pure coal	....	42.6	57.4	....	.41	....	....	....	....	....	....
Roslyn No. 7, ½ mile northeast of Clealum, composite sample.	9461	....	....	20 N.	15 E.	147	2.0	As received	5.0	30.1	46.8	12.15	.36	5.60	66.00	1.29	14.60	6,610	11,900
								Air dried	3.0	36.8	47.8	12.40	.37	5.49	67.35	1.32	13.07	6,745	12,140
								Dry coal	....	38.0	49.2	12.79	.38	5.31	69.46	1.36	10.70	6,955	12,520
								Pure coal	....	43.5	56.5	....	.44	6.09	79.65	1.56	12.26	7,975	14,360
Summit, 1 mile north of Clealum, Roslyn bed.	9403	SW.	14	20 N.	15 E.	148	2.6	As received	7.6	35.2	45.2	12.01	.44	5.65	63.88	1.32	16.70	6,430	11,580
								Air dried	5.2	36.1	46.4	12.33	.45	5.50	65.59	1.36	14.77	6,605	11,890
								Dry coal	....	38.1	48.9	13.01	.48	5.20	69.18	1.43	10.70	6,965	12,540
								Pure coal	....	43.8	56.2	....	.55	5.98	79.53	1.64	12.30	8,010	14,410
Cle Elum, No. 3 Extension, 1 mile north of Clealum, Roslyn bed.	9408	NW.	23	20 N.	15 E.	149	3.0	As received	8.5	34.9	44.5	12.15	.47	5.53	62.68	1.48	17.69	6,305	11,340
								Air dried	5.7	36.0	45.8	12.53	.48	5.36	64.62	1.53	15.48	6,500	11,700
								Dry coal	....	38.1	48.6	13.28	.51	5.01	68.52	1.62	11.06	6,890	12,400
								Pure coal	....	44.0	56.0	....	.59	5.78	79.01	1.87	12.75	7,945	14,300
Cle Elum, No. 2 Extension, 1 mile north of Clealum, Roslyn bed.	9409	SE.	23	20 N.	15 E.	150	2.8	As received	8.5	35.0	44.6	11.94	.43	5.52	63.35	1.43	17.33	6,350	11,430
								Air dried	5.9	36.0	45.8	12.28	.44	5.36	65.18	1.46	15.28	6,535	11,760
								Dry coal	....	38.3	48.7	13.05	.47	5.00	69.23	1.56	10.69	6,940	12,490
								Pure coal	....	44.0	56.0	....	.54	5.75	79.62	1.79	12.30	7,980	14,370

Analyses of coal samples from the State of Washington—Continued.

Kittitas County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location. Quarter.	Section.	Township.	Range.	Page.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ultimate Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Heat value. Calories.	British thermal units.
Cle Elum No. 2, ½ mile north of Clealum, Roslyn bed.	9472	NE.	25	20 N.	15 E.	150	3.9	As received...	8.0	34.5	45.5	12.04	0.45	5.50	63.64	1.39	16.98	6,365	11,480
								Air dried......	4.3	35.9	47.3	12.53	.47	5.28	66.22	1.45	14.05	6,620	11,920
								Dry coal......	....	37.5	49.4	13.09	.49	5.02	69.17	1.51	10.72	6,915	12,480
								Pure coal......	....	43.1	56.9	....	.56	5.78	79.59	1.74	12.33	7,960	14,330
Cle Elum No. 1 at Clealum, Roslyn bed.	9445	NW.	26	20 N.	15 E.	151	2.7	As received...	6.6	35.9	44.4	13.1	.35	......	......	......	......	......	....
								Air dried......	4.0	36.9	45.6	13.5	.36	......	......	......	......	......	....
								Dry coal......	....	38.4	47.6	14.0	.37	......	......	......	......	......	....
								Pure coal......	....	44.7	55.3	....	.43	......	......	......	......	......	....
Do..................	9446	SE.	26	20 N.	15 E.	151	2.3	As received...	7.5	35.2	44.1	13.2	.42	......	......	......	......	......	....
								Air dried......	5.3	36.0	45.2	13.5	.43	......	......	......	......	......	....
								Dry coal......	....	38.0	47.7	14.3	.45	......	......	......	......	......	....
								Pure coal......	....	44.4	55.6	....	.53	......	......	......	......	......	....
Do..................	9447	NE.	25	20 N.	15 E.	151	5.1	As received...	9.9	33.5	44.8	11.8	.39	......	......	......	......	......	....
								Air dried......	5.1	35.3	47.2	12.4	.41	......	......	......	......	......	....
								Dry coal......	....	37.2	49.7	13.1	.43	......	......	......	......	......	....
								Pure coal......	....	42.8	57.2	....	.40	......	......	......	......	......	....
Cle Elum No. 1 at Clealum, composite sample.	9467	....	......	20 N.	15 E.	152	3.4	As received...	7.9	34.6	44.8	12.68	.43	5.76	62.84	1.31	16.98	6,340	11,410
								Air dried......	4.7	35.8	46.4	13.13	.44	5.57	65.05	1.36	14.45	6,565	11,820
								Dry coal......	....	37.6	48.6	13.77	.47	5.30	68.23	1.42	10.81	6,885	12,390
								Pure coal......	....	43.6	56.4	....	.54	6.15	79.13	1.65	12.53	7,965	14,370

Lewis County.

Name of mine or form of exposure.	Laboratory No.	Location. Quarter.	Section.	Township.	Range.	Page.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ultimate Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Heat value. Calories.	British thermal units.
Prospect on Carlton Creek.	9093	NW.	29	15 N.	11 E.	153	7.8	As received...	9.8	6.8	13.6	69.8	0.25	......	......	......	......	1,115	2,000
								Air dried......	2.1	7.4	14.8	75.7	.27	......	......	......	......	1,205	2,170
								Dry coal......	....	7.6	15.1	77.3	.28	......	......	......	......	1,235	2,220
								Pure coal......	....	33.4	66.6	....	1.24	......	......	......	......	5,440	9,790
Do..................	9091	SE.	1	14 N.	10 E.	153	3.5	As received...	4.2	10.5	51.2	34.05	.48	3.08	53.61	0.87	7.91	4,935	8,880
								Air dried......	.8	10.8	53.1	35.28	.50	2.79	55.55	.90	4.98	5,115	9,200
								Dry coal......	....	10.9	53.5	35.56	.50	2.73	55.97	.91	4.33	5,155	9,300
								Pure coal......	....	17.0	83.0	....	.78	4.24	86.85	1.41	6.72	[illegible],000	14,400

Prospect A on Summit Creek, Primrose bed.	9101	NW.	13	14 N.	10 E.	154	2.8	As received	3.6	8.4	59.6	28.40	.66	3.17	60.00	.99	6.78	5,580	10,050
								Air dried	.8	8.6	61.4	29.22	.68	2.91	61.73	1.02	4.41	5,740	10,340
								Dry coal		8.7	61.8	29.46	.68	2.87	62.23	1.03	3.73	5,790	10,420
								Pure coal		12.3	87.7		.96	4.07	88.20	1.46	5.31	8,205	14,770
Do	9097	NW.	13	14 N.	10 E.	154	3.7	As received	5.1	8.6	36.6	49.7	1.00					3,325	5,980
								Air dried	1.5	8.9	38.0	51.6	1.04					3,455	6,210
								Dry coal		9.0	38.6	52.4	1.05					3,505	6,310
								Pure coal		19.0	81.0		2.21					7,370	13,260
Do	9102	NW.	13	14 N.	10 E.	154	3.0	As received	3.9	8.6	52.1	35.4	.66					4,820	8,860
								Air dried	.9	8.9	53.7	36.5	.68					4,970	8,950
								Dry coal		8.9	54.2	36.9	.69					5,015	9,030
								Pure coal		14.1	85.9		1.09					7,945	14,300
Do	9099	NW.	13	14 N.	10 E.	154	3.1	As received	4.0	7.4	71.1	17.53	.55	3.35	71.41	1.30	5.86	6,615	11,900
								Air dried	.9	7.6	73.4	18.09	.57	3.11	73.69	1.34	3.20	6,825	12,280
								Dry coal		7.7	74.0	18.25	.57	3.03	74.33	1.35	2.47	6,885	12,390
								Pure coal		9.4	90.6		.70	3.71	90.92	1.65	3.02	8,420	15,150
Do	9100	NW.	13	14 N.	10 E.	154	2.0	As received	2.7	7.1	79.5	10.67	.62	3.48	79.22	1.32	4.69	7,420	13,350
								Air dried	.7	7.3	81.1	10.89	.63	3.33	80.84	1.35	2.96	7,570	13,620
								Dry coal		7.3	81.7	10.96	.64	3.27	81.39	1.36	2.38	7,620	13,720
								Pure coal		8.2	91.8		.72	3.67	91.41	1.53	2.67	8,560	15,410
Prospect B on Summit Creek.	9098	NW.	13	14 N.	10 E.	155	2.9	As received	3.7	7.3	47.8	41.16	.70	2.64	47.64	.87	6.99	4,440	7,990
								Air dried	.8	7.6	49.2	42.39	.72	2.39	49.06	.91	4.53	4,575	8,230
								Dry coal		7.7	49.6	42.74	.73	2.31	49.47	.91	3.84	4,610	8,300
								Pure coal		13.3	86.7		1.27	4.03	86.39	1.59	6.72	8,050	14,490
Prospect C on Summit Creek.	9092	NW.	13	14 N.	10 E.	156	2.1	As received	2.9	8.6	81.9	6.6	.78					7,640	13,750
								Air dried	.8	8.8	83.6	6.8	.80					7,805	14,050
								Dry coal		8.9	84.3	6.8	.80					7,870	14,170
								Pure coal		9.5	90.5		.86					8,440	15,200
Prospects east of Cowlitz River.	9090	SE.	7	13 N.	10 E.	156	5.6	As received	7.4	4.8	52.0	35.8	.74					4,555	8,200
								Air dried	1.9	5.1	55.1	37.9	.78					4,825	8,690
								Dry coal		5.2	56.2	38.6	.80					4,920	8,850
								Pure coal		8.4	91.6		1.30					8,010	14,420
Prospect near Ladd and Glenavon.	6488	SE.	14	13 N.	4 E.	157	6.0	As received	8.5	27.3	44.8	19.4	.27					5,830	10,500
								Air dried	2.7	29.0	47.7	20.6	.29					6,205	11,170
								Dry coal		29.9	49.0	21.1	.30					6,375	11,470
								Pure coal		37.9	62.1		.38					8,085	14,550
Do	6489	NE.	26	14 N.	4 E.	157	5.1	As received	9.1	27.8	33.2	29.9	.63					4,475	8,050
								Air dried	4.2	29.3	35.0	31.5	.66					4,715	8,480
								Dry coal		30.6	36.5	32.9	.69					4,925	8,860
								Pure coal		45.6	54.4		1.03					7,330	13,200

Analyses of coal samples from the State of Washington—Continued.

Lewis County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location.				Page.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
		Quarter.	Section.	Township.	Range.				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Prospects near Ladd and Glenavon.	6490	NE.	10	13 N.	4 E.	157	8.7	As received	13.5	21.7	49.6	15.2	0.35					5,335	9,610
								Air dried	5.3	23.8	54.3	16.6	.38					5,845	10,530
								Dry coal		25.1	57.3	17.6	.40					6,165	11,100
								Pure coal		30.5	69.5		.49					7,485	13,470
Do	6495	SE.	34	14 N.	4 E.	157	8.5	As received	11.2	31.3	47.1	10.4	.56					6,195	11,160
								Air dried	2.9	34.2	51.5	11.4	.61					6,775	12,200
								Dry coal		35.2	53.1	11.7	.63					6,975	12,560
								Pure coal		39.9	60.1		.71					7,905	14,230
Do	6496	NW.	14	13 N.	4 E.	157	5.8	As received	8.1	4.6	62.4	24.9	.30					5,455	9,820
								Air dried	2.5	4.9	66.2	26.4	.32					5,795	10,420
								Dry coal		5.0	67.9	27.1	.33					5,940	10,690
								Pure coal		6.8	93.2		.45					8,150	14,670
East Creek-Ladd at Ladd, No. 2 bed.	9882	SW.	13	14 N.	4 E.	159	2.7	As received	4.1	26.9	51.7	17.31	1.26	4.87	66.51	1.31	8.74	6,590	11,860
								Air dried	1.4	27.7	53.1	17.79	1.29	4.70	68.36	1.35	6.51	6,770	12,190
								Dry coal		28.1	53.9	18.05	1.31	4.61	69.34	1.37	5.32	6,870	12,360
								Pure coal		34.2	65.8		1.60	5.63	84.62	1.67	6.48	8,380	15,090
East Creek-Ladd at Ladd, No. 3 bed.	9881	NW.	13	14 N.	4 E.	159	3.3	As received	6.3	34.7	37.6	21.4	.83					5,575	10,030
								Air dried	3.1	35.8	38.9	22.2	.86					5,765	10,370
								Dry coal		37.0	40.1	22.9	.89					5,950	10,710
								Pure coal		47.9	52.1		1.15					7,710	13,880
Do	9880	NW.	13	14 N.	4 E.	159	4.4	As received	7.2	34.4	37.8	20.6	.53					5,615	10,110
								Air dried	3.0	35.9	39.5	21.6	.55					5,875	10,570
								Dry coal		37.0	40.8	22.2	.57					6,050	10,890
								Pure coal		47.6	52.4		.73					7,780	14,010
East Creek-Ladd at Ladd, No. 4 bed.	9879	NW	13	14 N.	4 E.	159	5.2	As received	8.6	32.5	34.4	24.5	.85					5,135	9,240
								Air dried	3.6	34.3	36.3	25.8	.90					5,415	9,750
								Dry coal		35.6	37.6	26.8	.93					5,615	10,110
								Pure coal		48.6	51.4		1.27					7,670	13,800

East Creek-Ladd at Ladd, No. 2 bed.	6493	SW.	12	14 N.	4 E.	159	2.4	As received....	4.4	26.6	51.5	17.5	1.05	......	......	......	......	6,330	11,400
								Air dried......	2.0	27.3	52.8	17.9	1.08	......	......	......	......	6,490	11,680
								Dry coal......	......	27.8	53.9	18.3	1.10	......	......	......	......	6,625	11,920
								Pure coal......	......	34.0	66.0	......	1.35	......	......	......	......	8,110	14,600
East Creek-Ladd at Ladd, No. 3 bed.	6494	NW.	13	14 N.	4 E.	159	2.3	As received....	5.6	33.9	40.4	20.1	.61	......	......	......	......	5,775	10,390
								Air dried......	3.4	34.7	41.3	20.6	.62	......	......	......	......	5,910	10,630
								Dry coal......	......	35.9	42.8	21.3	.65	......	......	......	......	6,115	11,010
								Pure coal......	......	45.7	54.3	......	.83	......	......	......	......	7,770	13,980
East Creek-Ladd at Ladd, No. 4 bed.	6492	NW.	13	14 N.	4 E.	159	2.9	As received....	6.4	31.2	40.1	22.3	.88	......	......	......	......	5,470	9,840
								Air dried......	3.6	32.1	41.3	23.0	.91	......	......	......	......	5,630	10,130
								Dry coal......	......	33.3	42.9	23.8	.94	......	......	......	......	5,845	10,520
								Pure coal......	......	43.7	56.3	......	1.23	......	......	......	......	7,665	13,800
East Creek-Ladd at Ladd, washed coal from No. 2 bed.	6491	SW.	12	14 N.	4 E.	160	8.9	As received....	10.7	25.9	47.1	16.3	.84	......	......	......	......	5,865	10,560
								Air dried......	2.0	28.4	51.7	17.9	.92	......	......	......	......	6,440	11,590
								Dry coal......	......	29.0	52.7	18.3	.94	......	......	......	......	6,570	11,830
								Pure coal......	......	35.5	64.5	......	1.15	......	......	......	......	8,040	14,480
Mendota at Mendota......	10324	SW.	3	14 N.	1 W.	161	11.5	As received....	20.5	33.5	33.7	12.31	1.28	6.24	48.91	.82	30.44	4,830	8,690
								Air dried......	10.2	37.8	38.1	13.91	1.45	5.61	55.27	.93	22.83	5,455	9,820
								Dry coal......	......	42.1	42.4	15.49	1.61	4.98	61.56	1.03	15.33	6,075	10,940
								Pure coal......	......	49.8	50.2	......	1.91	5.89	72.84	1.22	18.14	7,190	12,940
Do..................	10323	SW.	3	14 N.	1 W.	161	9.6	As received....	19.3	33.8	34.3	12.62	1.17	5.99	50.00	.83	29.39	4,920	8,850
								Air dried......	10.7	37.4	37.9	13.96	1.29	5.44	55.31	.92	23.08	5,440	9,790
								Dry coal......	......	41.9	42.5	15.63	1.45	4.77	61.92	1.03	15.20	6,090	10,960
								Pure coal......	......	49.7	50.3	......	1.72	5.65	73.37	1.22	18.04	7,220	12,900
Richmond, 1½ miles northeast of Centralia.	9177	SW.	34	15 N.	2 W.	162	14.9	As received....	26.7	32.8	32.1	8.41	1.52	6.60	45.85	.79	36.83	4,460	8,030
								Air dried......	13.9	38.5	37.7	9.88	1.79	5.80	53.88	.93	27.72	5,240	9,430
								Dry coal......	......	44.7	43.8	11.47	2.07	4.95	62.56	1.08	17.87	6,085	10,950
								Pure coal......	......	50.5	49.5	......	2.34	5.59	70.68	1.22	20.17	6,870	12,370
Superior No. 1, 1 mile north of Chehalis.	9942	......	....	14 N.	2 W.	163	14.3	As received....	27.2	33.8	28.1	10.92	.33	6.27	43.88	.80	37.80	4,205	7,570
								Air dried......	15.0	39.5	32.8	12.74	.38	5.46	51.20	.93	29.29	4,905	8,830
								Dry coal......	......	46.4	38.6	14.99	.45	4.46	60.25	1.10	18.75	5,775	10,390
								Pure coal......	......	54.6	45.4	......	.53	5.25	70.87	1.29	22.06	6,790	12,230
Superior No. 2 at Chehalis.	9941	......	....	14 N.	2 W.	163	17.1	As received....	30.5	34.9	29.6	4.95	1.25	6.89	45.48	.75	40.68	4,410	7,930
								Air dried......	16.2	42.1	35.7	5.97	1.51	6.02	54.86	.90	30.74	5,320	9,580
								Dry coal......	......	50.3	42.6	7.12	1.80	5.04	65.44	1.08	19.52	6,345	11,420
								Pure coal......	......	54.1	45.9	......	1.94	5.43	70.46	1.16	21.01	6,830	12,290
Twin City, 1 mile northeast of Chehalis.	9945	......	....	14 N.	2 W.	164	19.3	As received....	30.6	31.8	27.9	9.74	.27	6.56	41.82	.73	40.88	4,015	7,230
								Air dried......	14.0	39.4	34.5	12.07	.34	5.47	51.82	.90	29.40	4,975	8,960
								Dry coal......	......	45.8	40.2	14.04	.39	4.55	60.26	1.05	19.71	5,785	10,420
								Pure coal......	......	53.3	46.7	......	.45	5.29	70.10	1.22	22.94	6,730	12,120

Analyses of coal samples from the State of Washington—Continued.

Lewis County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location: Quarter.	Location: Section.	Location: Township.	Location: Range.	Page.	Air-drying loss.	Form of analysis.	Proximate: Moisture.	Proximate: Volatile matter.	Proximate: Fixed carbon.	Proximate: Ash.	Ultimate: Sulphur.	Ultimate: Hydrogen.	Ultimate: Carbon.	Ultimate: Nitrogen.	Ultimate: Oxygen.	Heat value: Calories.	Heat value: British thermal units.
Chehalis, 2 miles east of Chehalis.	9944	SE.	28	14 N.	2 W.	165	15.7	As received	29.1	34.7	28.5	7.67	1.77	6.69	45.28	0.74	37.85	4,415	7,940
								Air dried	16.0	41.1	33.8	9.10	2.10	5.87	53.71	.88	28.34	5,235	9,420
								Dry coal	......	48.9	40.3	10.83	2.50	4.87	63.91	1.04	16.85	6,230	11,210
								Pure coal	......	54.9	45.1	......	2.80	5.46	71.68	1.17	18.89	6,985	12,560
Sheldon, 3 miles east of Chehalis.	9943	......	......	14 N.	2 W.	165	15.2	As received	29.9	34.0	30.4	5.75	.58	6.98	45.50	.85	40.34	4,405	7,930
								Air dried	17.3	40.0	35.9	6.78	.68	6.24	53.65	1.00	31.65	5,195	9,350
								Dry coal	......	48.4	43.4	8.19	.83	5.22	64.89	1.21	19.66	6,285	11,310
								Pure coal	......	52.7	47.3	......	.90	5.69	70.68	1.32	21.41	6,845	12,320
Crescent, 4 miles northwest of Littell.	9940	......	......	14 N.	3 W.	166	19.1	As received	32.1	31.9	27.3	8.7	2.97	......	......	......	......	3,970	7,140
								Air dried	16.1	39.4	33.8	10.7	3.66	......	......	......	......	4,905	8,830
								Dry coal	......	47.0	40.2	12.8	4.36	......	......	......	......	5,850	10,530
								Pure coal	......	53.9	46.1	......	5.00	......	......	......	......	6,705	12,070

Pierce County

Name of mine or form of exposure.	Laboratory No.	Location: Quarter.	Location: Section.	Location: Township.	Location: Range.	Page.	Air-drying loss.	Form of analysis.	Proximate: Moisture.	Proximate: Volatile matter.	Proximate: Fixed carbon.	Proximate: Ash.	Ultimate: Sulphur.	Ultimate: Hydrogen.	Ultimate: Carbon.	Ultimate: Nitrogen.	Ultimate: Oxygen.	Heat value: Calories.	Heat value: British thermal units.
Burnett at Burnett, No. 2 bed.	9891	SE.	21	19 N.	6 E.	168	2.4	As received	3.7	36.0	52.2	8.13	0.76	5.56	73.80	2.00	9.68	7,540	13,570
								Air dried	1.3	37.0	53.4	8.33	.78	5.42	75.71	2.06	7.71	7,725	13,900
								Dry coal	......	37.4	54.2	8.44	.79	5.35	76.72	2.08	6.62	7,820	14,080
								Pure coal	......	40.9	59.1	......	.86	5.84	83.79	2.27	7.24	8,550	15,380
Burnett at Burnett, No. 3 bed.	9890	NW.	21	19 N.	6 E.	168	1.3	As received	3.2	35.0	49.3	12.46	.38	5.28	70.74	1.97	9.17	7,065	12,720
								Air dried	1.9	35.5	50.0	12.62	.39	5.21	71.67	2.00	8.11	7,160	12,890
								Dry coal	......	36.2	50.9	12.86	.39	5.08	73.08	2.04	6.55	7,300	13,140
								Pure coal	......	41.5	58.5	......	.45	5.83	83.87	2.34	7.51	8,380	15,080
Do	9889	NW.	21	19 N.	6 E.	168	1.8	As received	3.6	36.8	45.6	14.00	.38	5.36	67.76	1.75	10.66	6,870	12,370
								Air dried	1.8	37.5	46.3	14.35	.39	5.28	69.00	1.78	9.28	7,000	12,600
								Dry coal	......	38.2	47.2	14.62	.39	5.15	70.29	1.82	7.73	7,130	12,830
								Pure coal	......	44.8	55.2	......	.46	6.03	82.33	2.13	9.05	8,350	15,030

Do.	9888	NW.	21	19 N.	6 E.	168	2.7	As received	4.7	35.2	46.9	13.19	.37	5.36	67.64	1.93	11.51	6,820	12,270
								Air dried	2.0	36.2	48.2	13.56	.38	5.20	69.52	1.98	9.36	7,005	12,610
								Dry coal	....	37.0	49.2	13.83	.39	5.08	70.94	2.02	7.74	7,150	12,870
								Pure coal	....	42.9	57.1	....	.45	5.90	82.33	2.34	8.98	8,300	14,940
Burnett at Burnett, lump coal.	9887	....	16	19 N.	6 E.	169	1.4	As received	3.3	36.8	46.8	13.15	.41	5.31	68.77	1.95	10.41	6,960	12,530
								Air dried	1.9	37.3	47.5	13.34	.42	5.22	69.75	1.98	9.29	7,060	12,710
								Dry coal	....	38.0	48.4	13.59	.42	5.12	71.08	2.02	7.77	7,195	12,950
								Pure coal	....	44.0	56.0	....	.49	5.93	82.25	2.34	8.99	8,325	14,990
Burnett at Burnett, washed coal.	9886	....	16	19 N.	6 E.	169	6.1	As received	7.7	34.4	46.6	11.35	.56	5.69	67.50	1.88	13.02	6,840	12,310
								Air dried	1.7	36.6	49.6	12.09	.60	5.34	71.89	2.00	8.08	7,280	13,110
								Dry coal	....	37.2	50.5	12.29	.61	5.23	73.15	2.04	6.68	7,410	13,340
								Pure coal	....	42.5	57.5	....	.70	5.96	83.40	2.33	7.61	8,450	15,210
Black Carbon, ¼ mile west of Pittsburg, Black Carbon bed.	9892	NW.	22	19 N.	6 E.	170	2.7	As received	5.1	32.8	39.1	22.96	.54	4.76	57.33	1.70	12.71	5,800	10,440
								Air dried	2.5	33.7	40.2	23.60	.55	4.58	58.92	1.75	10.60	5,960	10,730
								Dry coal	....	34.6	41.2	24.19	.57	4.42	60.40	1.79	8.63	6,110	11,000
								Pure coal	....	45.6	54.4	....	.75	5.83	79.67	2.36	11.39	8,060	14,510
Pittsburg at Pittsburg, Lady Wellington bed.	9895	....	14	19 N.	6 E.	171	3.5	As received	6.7	32.7	42.1	18.47	.41	5.00	58.85	1.64	15.63	5,910	10,640
								Air dried	3.3	33.9	43.7	19.14	.42	4.78	60.98	1.70	12.98	6,125	11,020
								Dry coal	....	35.1	45.1	19.79	.44	4.56	63.06	1.76	10.39	6,335	11,400
								Pure coal	....	43.8	56.2	....	.55	5.68	78.63	2.19	12.95	7,895	14,210
Pittsburg at Pittsburg, Pittsburg bed.	9894	....	14	19 N.	6 E.	171	2.2	As received	4.7	32.7	42.2	20.38	.55	4.86	59.19	1.84	13.18	6,030	10,860
								Air dried	2.6	33.4	43.2	20.84	.56	4.72	60.52	1.88	11.48	6,165	11,100
								Dry coal	....	34.3	44.3	21.38	.58	4.55	62.10	1.93	9.46	6,330	11,390
								Pure coal	....	43.7	56.3	....	.74	5.79	78.98	2.45	12.04	8,050	14,490
Pittsburg at Pittsburg, washed coal.	9893	....	14	19 N.	6 E.	172	4.7	As received	7.8	31.3	40.5	20.41	.40	5.03	57.19	1.65	15.32	5,710	10,270
								Air dried	3.3	32.8	42.5	21.42	.42	4.73	60.01	1.73	11.69	5,990	10,780
								Dry coal	....	33.9	44.0	22.13	.43	4.51	62.02	1.79	9.12	6,190	11,140
								Pure coal	....	43.6	56.4	....	.55	5.79	79.65	2.30	11.71	7,945	14,300
Wilkeson at Wilkeson, No. 2 bed.	9905	NW.	3	18 N.	6 E.	173	2.8	As received	3.7	27.1	56.6	12.60	.45	5.08	72.54	2.19	7.14	7,210	12,980
								Air dried	.9	27.8	58.3	12.96	.46	4.91	74.63	2.25	4.79	7,420	13,350
								Dry coal	....	28.1	58.8	13.08	.47	4.85	75.32	2.27	4.01	7,485	13,470
								Pure coal	....	32.4	67.6	....	.54	5.58	86.66	2.61	4.61	8,615	15,500
Do.	9904	SE.	34	19 N.	6 E.	173	2.3	As received	3.1	18.5	54.9	23.5	.43	....	....	....	....	6,130	11,030
								Air dried	.8	18.9	56.2	24.1	.44	....	....	....	....	6,275	11,290
								Dry coal	....	19.1	56.7	24.2	.44	....	....	....	....	6,325	11,380
								Pure coal	....	25.2	74.8	....	.58	....	....	....	....	8,350	15,030
Do.	9903	SE.	34	19 N.	6 E.	174	2.8	As received	3.6	19.1	61.3	16.05	.49	4.41	70.52	1.94	6.59	6,845	12,320
								Air dried	.8	19.7	63.0	16.51	.50	4.22	72.55	2.00	4.22	7,040	12,670
								Dry coal	....	19.9	63.5	16.64	.51	4.16	73.12	2.01	3.56	7,100	12,770
								Pure coal	....	23.8	76.2	....	.61	4.99	87.71	2.41	4.28	8,510	15,330

Analyses of coal samples from the State of Washington—Continued.

Pierce County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location. Quarter.	Location. Section.	Location. Township.	Location. Range.	Page.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Heat value. Calories.	Heat value. British thermal units.
Wilkeson at Wilkeson, No. 3 bed.	9902	NW.	3	18 N.	6 E.	173	1.6	As received...	2.5	27.7	61.3	8.53	0.42	5.23	76.94	2.05	6.83	7,715	13,890
								Air dried......	.9	28.1	62.3	8.67	.43	5.13	78.19	2.08	5.50	7,840	14,120
								Dry coal......	....	28.4	62.8	8.75	.43	5.07	78.93	2.10	4.72	7,915	14,250
								Pure coal.....	....	31.1	68.9	....	.47	5.56	86.50	2.30	5.17	8,675	15,620
Do................	9901	NW.	3	18 N.	6 E.	173	1.2	As received...	2.4	24.5	55.3	17.8	.48	......	......	......	......	6,810	12,260
								Air dried......	1.1	24.8	56.0	18.1	.49	......	......	......	......	6,890	12,410
								Dry coal......	....	25.1	56.6	18.3	.49	......	......	......	......	6,970	12,550
								Pure coal.....	....	30.7	69.3	....	.60	......	......	......	......	8,530	15,350
Do................	9900	NE.	34	19 N.	6 E.	173	4.3	As received...	5.3	20.4	59.3	14.95	.45	4.52	69.79	1.91	8.38	6,835	12,300
								Air dried......	1.1	21.4	61.9	15.62	.47	4.22	72.93	2.00	4.76	7,140	12,850
								Dry coal......	....	21.6	62.6	15.79	.48	4.15	73.73	2.02	3.83	7,220	12,990
								Pure coal.....	....	25.6	74.4	....	.57	4.93	87.55	2.40	4.55	8,570	15,430
Wilkeson at Wilkeson, No. 7 bed.	9899	NW.	34	19 N.	6 E.	173	4.9	As received...	5.9	23.2	61.1	9.76	.41	5.09	74.04	2.17	8.53	7,315	13,160
								Air dried......	1.1	24.3	64.3	10.26	.43	4.78	77.86	2.28	4.39	7,690	13,840
								Dry coal......	....	24.6	65.0	10.38	.44	4.71	78.72	2.31	3.44	7,775	14,000
								Pure coal.....	....	27.5	72.5	....	.49	5.26	87.84	2.58	3.83	8,675	15,620
Wilkeson at Wilkeson, rewashed coal.	9898	....	27	19 N.	6 E.	175	5.5	As received...	6.6	23.3	56.5	13.57	.46	5.04	69.29	1.98	9.66	6,850	12,330
								Air dried......	1.1	24.7	59.8	14.36	.49	4.69	73.32	2.10	5.04	7,245	13,040
								Dry coal......	....	25.0	60.5	14.53	.49	4.61	74.19	2.12	4.06	7,330	13,200
								Pure coal.....	....	29.2	70.8	....	.57	5.39	86.80	2.48	4.76	8,560	15,440
Gale Creek at Wilkeson, No. 1 bed.	9908	NE.	28	19 N.	6 E.	176	3.4	As received...	5.5	36.4	50.0	8.06	.80	5.70	71.24	1.91	12.29	7,235	13,020
								Air dried......	2.2	37.7	51.8	8.34	.83	5.51	73.75	1.98	9.59	7,400	13,480
								Dry coal......	....	38.5	53.0	8.53	.85	5.39	75.38	2.02	7.83	7,655	13,780
								Pure coal.....	....	42.1	57.9	....	.93	5.89	82.41	2.21	8.56	8,370	15,080
Gale Creek at Wilkeson, No. 2 bed.	9909	NE.	28	19 N.	6 E.	176	2.4	As received...	3.9	35.0	55.1	5.98	.96	5.63	74.97	1.95	10.51	7,635	13,740
								Air dried......	1.6	35.9	56.4	6.13	.98	5.49	76.81	2.00	8.59	7,826	14,090
								Dry coal......	....	36.5	57.3	6.22	1.00	5.41	78.01	2.03	7.33	7,945	14,300
								Pure coal.....	....	38.9	61.1	....	1.07	5.77	83.18	2.16	7.83	8,475	15,260

Gale Creek at Wilkeson, Queen bed.	9910	NE.	28	19 N.	6 E.	176	1.4	As received	2.8	33.8	53.8	9.56	1.01	5.44	73.88	2.00	8.11,	7,475	13,450
								Air dried	1.4	34.3	54.6	9.70	1.02	5.36	74.93	2.03	6.96	7,580	13,640
								Dry coal		34.8	55.4	9.83	1.04	5.28	76.00	2.06	5.79	7,685	13,840
								Pure coal		38.5	61.5		1.15	5.86	84.28	2.28	6.43	8,525	15,340
Willis at South Willis, Windsor bed.	9906	NE.	22	19 N.	6 E.	177	1.4	As received	3.1	30.2	45.5	21.18	.41	4.82	62.56	1.56	9.47	6,245	11,240
								Air dried	1.8	30.6	46.1	21.48	.42	4.73	63.45	1.58	8.34	6,330	11,400
								Dry coal		31.1	47.0	21.87	.42	4.62	64.59	1.61	6.89	6,445	11,600
								Pure coal		39.9	60.1		.54	5.91	82.67	2.06	8.82	8,250	14,850
Willis at South Willis, washed coal.	9907		22	19 N.	6 E.	177	5.0	As received	7.1	28.4	42.0	22.51	.43	5.13	57.93	1.45	12.55	5,770	10,380
								Air dried	2.2	29.9	44.2	23.69	.45	4.81	60.98	1.53	8.54	6,075	10,930
								Dry coal		30.6	45.2	24.22	.46	4.67	62.34	1.56	6.75	6,270	11,170
								Pure coal		40.3	59.7		.61	6.16	82.26	2.06	8.91	8,190	14,750
Brier Hill at Wilkeson	9897	NW.	28	19 N.	6 E.	178	2.3	As received	4.7	29.8	37.0	28.50	1.15	4.30	52.42	1.74	11.89	5,300	9,540
								Air dried	2.4	30.5	37.9	29.17	1.18	4.13	53.65	1.78	10.09	5,425	9,760
								Dry coal		31.3	38.8	29.91	1.21	3.97	55.01	1.83	8.07	5,560	10,010
								Pure coal		44.6	55.4		1.73	5.66	78.48	2.61	11.52	7,930	14,280
Snell, 2 miles southeast of Wilkeson.	9896	NW.	26	18 N.	6 E.	179	5.4	As received	6.7	25.7	50.1	17.5	.78					6,425	11,560
								Air dried	1.4	27.2	52.9	18.5	.82					6,790	12,220
								Dry coal		27.6	53.7	18.7	.84					6,885	12,390
								Pure coal		34.0	66.0		1.03					8,470	15,250
Carbon Hill at Carbonado, No. 11 bed.	9570	SW.	4	18 N.	6 E.	180	2.7	As received	4.4	28.5	47.6	19.51	.39	4.85	62.34	1.78	11.13	6,260	11,270
								Air dried	1.8	29.2	48.9	20.05	.40	4.68	64.07	1.83	8.97	6,435	11,580
								Dry coal		29.8	49.8	20.42	.41	4.56	65.25	1.86	7.50	6,555	11,790
								Pure coal		37.4	62.6		.52	5.73	81.99	2.34	9.42	8,235	14,820
Carbon Hill at Carbonado, No. 9 bed.	9556	SW.	4	18 N.	6 E.	181	2.4	As received	3.7	29.0	51.8	15.50	.52	5.08	67.37	2.13	9.40	6,740	12,130
								Air dried	1.4	29.7	53.0	15.88	.53	4.93	69.03	2.18	7.45	6,905	12,430
								Dry coal		30.1	53.8	16.10	.54	4.84	69.99	2.21	6.32	7,000	12,600
								Pure coal		35.9	64.1		.64	5.77	83.42	2.63	7.54	8,345	15,020
Carbon Hill at Carbonado, No. 5 bed.	9564	NW.	9	18 N.	6 E.	180	1.9	As received	3.6	29.7	50.3	16.38	.56	4.94	65.52	2.10	10.50	6,505	11,710
								Air dried	1.7	30.3	51.3	16.70	.57	4.82	66.79	2.14	8.98	6,630	11,930
								Dry coal		30.8	52.2	16.99	58	4.71	67.96	2.18	7.58	6,745	12,140
								Pure coal		37.1	62.9		.70	5.67	81.87	2.63	9.13	8,130	14,630
Carbon Hill at Carbonado, No. 1 bed.	9572	NW.	4	18 N.	6 E.	181	1.8	As received	3.4	32.2	49.5	14.88	.45	5.33	67.24	2.00	10.10	6,805	12,250
								Air dried	1.6	32.8	50.4	15.15	.46	5.22	68.47	2.04	8.66	6,930	12,470
								Dry coal		33.3	51.3	15.40	.47	5.12	69.59	2.07	7.35	7,040	12,680
								Pure coal		39.4	60.6		.56	6.05	82.26	2.45	8.68	8,325	14,880
Do	2460	NW.	4	18 N.	6 E.	181	2.4	As received	4.1	31.1	50.2	14.6	.35						
								Air dried	1.7	31.9	51.4	15.0	.36						
								Dry coal		32.5	52.3	15.2	.36						
								Pure coal		38.3	61.7		.42						

Analyses of coal samples from the State of Washington—**Continued.**

Pierce County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location: Quarter.	Location: Section.	Location: Township.	Location: Range.	Page.	Air-drying loss.	Form of analysis.	Proximate: Moisture.	Proximate: Volatile matter.	Proximate: Fixed carbon.	Proximate: Ash.	Ultimate: Sulphur.	Ultimate: Hydrogen.	Ultimate: Carbon.	Ultimate: Nitrogen.	Ultimate: Oxygen.	Heat value: Calories.	Heat value: British thermal units.
Carbon Hill at Carbonado, No. 4 bed.	9562	NW.	4	18 N.	6 E.	181	2.0	As received	3.2	34.9	51.5	10.43	0.32	5.48	72.54	1.89	9.34	7,340	13,210
								Air dried	1.2	35.6	52.6	10.64	.33	5.37	74.02	1.93	7.71	7,490	13,480
								Dry coal	......	36.0	53.2	10.77	.33	5.30	74.93	1.95	6.72	7,580	13,650
								Pure coal	......	40.3	59.7	......	.37	5.94	83.97	2.19	7.53	8,495	15,290
Carbon Hill at Carbonado, No. 3 Coking bed.	9565	NE.	4	18 N.	6 E.	181	3.5	As received	4.2	30.0	52.4	13.44	.30	5.10	70.13	1.88	9.15	7,035	12,660
								Air dried	.7	31.1	54.3	13.93	.31	4.88	72.67	1.95	6.26	7,290	13,120
								Dry coal	......	31.3	54.7	14.03	.31	4.84	73.19	1.96	5.67	7,340	13,210
								Pure coal	......	36.4	63.6	......	.36	5.63	85.12	2.28	6.61	8,540	15,370
Do	9555	NE.	4	18 N.	6 E.	181	3.0	As received	3.8	26.6	49.3	20.26	.39	5.01	63.85	1.93	8.56	6,400	11,520
								Air dried	.8	27.4	50.9	20.89	.40	4.82	65.82	1.99	6.08	6,595	11,870
								Dry coal	......	27.6	51.3	21.06	.41	4.77	66.38	2.01	5.37	6,650	11,970
								Pure coal	......	35.0	65.0	......	.52	6.04	84.09	2.55	6.80	8,425	15,170
Do	552-D	SE.	4	18 N.	6 E.	181	1.8	As received	2.9	30.9	50.1	16.1	.46	......	......	......	......	6,905	12,430
								Air dried	1.1	31.5	51.0	16.4	.47	......	......	......	......	7,035	12,660
								Dry coal	......	31.9	51.6	16.5	.47	......	......	......	......	7,115	12,810
								Pure coal	......	38.2	61.8	......	.56	......	......	......	......	8,525	15,340
Carbon Hill at Carbonado, run-of-mine coal.	787-D	SE.	4	18 N.	6 E.	184	3.3	As received	4.6	29.1	50.3	16.0	.45	......	......	......	......	6,740	12,130
								Air dried	1.3	30.1	52.0	16.6	.47	......	......	......	......	6,970	12,550
								Dry coal	......	30.5	52.8	16.7	.47	......	......	......	......	7,070	12,730
								Pure coal	......	36.6	63.4	......	.56	......	......	......	......	8,490	15,280
Carbon Hill at Carbonado, No. 2 Coking bed.	9557	SE.	4	18 N.	6 E.	181	2.8	As received	3.8	27.1	53.7	15.37	.39	4.99	68.20	2.02	9.03	6,850	12,330
								Air dried	1.1	27.8	55.3	15.81	.40	4.81	70.16	2.08	6.74	7,020	12,690
								Dry coal	......	28.1	55.9	15.98	.41	4.74	70.92	2.10	5.85	7,125	12,820
								Pure coal	......	33.5	66.5	......	.49	5.64	84.41	2.50	6.96	8,480	15,260
Carbon Hill at Carbonado, No. 1 Coking bed.	9569	SE.	4	18 N.	6 E.	182	2.2	As received	2.8	28.1	50.8	18.33	3.22	4.78	65.62	1.89	6.16	6,685	12,040
								Air dried	.6	28.7	51.9	18.75	3.29	4.64	67.10	1.93	4.29	6,835	12,310
								Dry coal	......	28.9	52.2	18.86	3.31	4.59	67.53	1.94	3.77	6,880	12,390
								Pure coal	......	35.6	64.4	......	4.08	5.60	83.22	2.39	4.65	8,480	15,260

Carbon Hill at Carbonado, Wingate bed.	9560	SE.	5	18 N.	6 E.	181	1.5	As received....	2.8	36.3	52.8	8.12	.49	5.80	74.07	2.10	9.42	7,520	13,540
								Air dried......	1.3	36.9	53.6	8.24	.50	5.72	75.20	2.13	8.21	7,635	13,740
								Dry coal......	....	37.4	54.3	8.35	.50	5.66	76.16	2.16	7.17	7,735	13,920
								Pure coal......	....	40.7	59.3	....	.55	6.18	83.10	2.36	7.81	8,435	15,190
Do................	9558	NE.	5	18 N.	6 E.	181	2.0	As received....	4.0	36.9	52.7	6.41	.52	5.84	74.02	2.16	11.05	7,380	13,280
								Air dried......	2.1	37.6	53.8	6.54	.53	5.73	75.53	2.20	9.47	7,530	13,560
								Dry coal......	....	38.4	54.9	6.68	.54	5.63	77.11	2.25	7.79	7,690	13,840
								Pure coal......	....	41.1	58.9	....	.58	6.03	82.63	2.41	8.35	8,240	14,830
Do................	9601	SE.	8	18 N.	6 E.	182	1.1	As received....	2.9	32.8	53.7	10.65	1.11	5.38	70.92	1.80	10.14	7,140	12,860
								Air dried......	1.8	33.2	54.2	10.77	1.12	5.32	71.71	1.82	9.26	7,220	13,000
								Dry coal......	....	33.8	55.2	10.96	1.14	5.21	73.00	1.85	7.84	7,350	13,230
								Pure coal......	....	38.0	62.0	....	1.28	5.85	81.99	2.08	8.80	8,255	14,860
Do................	2459	....	5	18 N.	6 E.	182	1.4	As received....	3.5	39.9	50.4	6.2	.86	....	....	....	....	....	....
								Air dried......	2.1	40.5	51.1	6.3	.87	....	....	....	....	....	....
								Dry coal......	....	41.3	52.2	6.5	.89	....	....	....	....	....	....
								Pure coal......	....	44.2	55.8	....	.95	....	....	....	....	....	....
Carbon Hill at Carbonado, Wingate lump coal.	9566	....	5	18 N.	6 E.	185	1.7	As received...	3.2	34.5	51.6	10.74	.69	5.32	71.46	1.97	9.82	7,250	13,050
								Air dried......	1.5	35.1	52.5	10.93	.70	5.22	72.70	2.00	8.45	7,375	13,280
								Dry coal......	....	35.6	53.3	11.09	.71	5.13	73.80	2.03	7.24	7,490	13,480
								Pure coal......	....	40.1	59.9	....	.80	5.77	83.00	2.28	8.15	8,425	15,160
Do................	9563	....	5	18 N.	6 E.	185	1.8	As received...	3.1	37.2	51.8	7.9	.44	....	....	....	....	7,555	13,590
								Air dried......	1.3	37.8	52.8	8.1	.45	....	....	....	....	7,690	13,840
								Dry coal......	....	38.3	53.5	8.2	.45	....	....	....	....	7,790	14,030
								Pure coal......	....	41.8	58.2	....	.49	....	....	....	....	8,490	15,280
Carbon Hill at Carbonado, washed Wingate coal.	9567	....	5	18 N.	6 E.	185	4.7	As received...	6.0	30.8	51.1	12.06	.82	5.34	67.73	2.03	12.02	6,845	12,320
								Air dried......	1.4	32.3	53.6	12.66	.86	5.06	71.07	2.13	8.22	7,180	12,930
								Dry coal......	....	32.8	54.4	12.83	.87	4.97	72.08	2.16	7.09	7,280	13,110
								Pure coal......	....	37.6	62.4	....	1.00	5.70	82.69	2.48	8.13	8,355	15,040
Carbon Hill at Carbonado, washed coal.	9561	....	5	18 N.	6 E.	185	2.5	As received...	3.7	32.4	51.5	12.45	.76	5.12	69.16	2.03	10.48	7,030	12,650
								Air dried......	1.2	33.2	52.8	12.77	.78	4.96	70.93	2.08	8.48	7,210	12,970
								Dry coal......	....	33.6	53.5	12.93	.79	4.89	71.82	2.11	7.46	7,300	13,140
								Pure coal......	....	38.6	61.4	....	.91	5.62	82.49	2.42	8.56	8,380	15,090
Carbon Hill at Carbonado, Douty washed coal.	9559	....	5	18 N.	6 E.	185	4.6	As received...	5.8	30.6	50.0	13.65	.42	5.34	66.54	1.92	12.13	6,705	12,070
								Air dried......	1.3	32.1	52.3	14.31	.44	5.06	69.75	2.01	8.43	7,030	12,650
								Dry coal......	....	32.5	53.0	14.49	.45	4.98	70.66	2.04	7.38	7,120	12,820
								Pure coal......	....	38.0	62.0	....	.53	5.82	82.64	2.39	8.62	8,330	14,990
Carbon Hill at Carbonado, Douty lump coal.	9571	....	5	18 N.	6 E.	185	2.3	As received...	3.5	30.6	48.2	17.7	.40	....	....	....	....	6,460	11,630
								Air dried......	1.3	31.3	49.3	18.1	.41	....	....	....	....	6,610	11,900
								Dry coal......	....	31.7	49.9	18.4	.41	....	....	....	....	6,695	12,050
								Pure coal......	....	38.8	61.2	....	.50	....	....	....	....	8,205	14,760

Analyses of coal samples from the State of Washington—Continued.

Pierce County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location.				Page.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
		Quarter.	Section.	Township.	Range.				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Carbon Hill at Carbonado, coal dust.	9568	....	5	18 N.	6 E.	185	17.4	As received...	18.8	25.0	38.6	17.6	0.59	......	......	......	......	5,210	9,380
								Air dried......	1.7	30.3	46.7	21.3	.72	......	......	......	......	6,310	11,350
								Dry coal......	......	30.8	47.5	21.7	.73	......	......	......	......	6,415	11,540
								Pure coal......	......	39.3	60.7	......	.93	......	......	......	......	8,195	14,750
Melmont at Melmont, No. 3 bed.	9579	NE.	16	18 N.	6 E.	186	2.9	As received...	3.6	23.6	59.3	13.47	.35	4.97	71.61	1.72	7.88	7,085	12,750
								Air dried......	.8	24.3	61.0	13.87	.36	4.79	73.75	1.77	5.46	7,295	13,130
								Dry coal......	......	24.5	61.5	13.98	.36	4.73	74.33	1.79	4.81	7,355	13,230
								Pure coal......	......	28.5	71.5	......	.42	5.50	86.41	2.08	5.59	8,550	15,380
Do..................	9578	NW.	15	18 N.	6 E.	186	2.3	As received...	3.1	21.4	60.6	14.9	.31	......	......	......	......	6,890	12,400
								Air dried......	.8	21.9	62.0	15.3	.32	......	......	......	......	7,055	12,700
								Dry coal......	......	22.1	62.5	15.4	.32	......	......	......	......	7,115	12,800
								Pure coal......	......	26.1	73.9	......	.38	......	......	......	......	8,410	15,140
Melmont at Melmont, No. 2 bed.	9576	SW.	15	18 N.	6 E.	186	4.4	As received...	5.6	12.0	63.9	18.5	.38	......	......	......	......	6,440	11,600
								Air dried......	1.2	12.6	66.8	19.4	.40	......	......	......	......	6,740	12,130
								Dry coal......	......	12.7	67.6	19.7	.40	......	......	......	......	6,825	12,280
								Pure coal......	......	15.8	84.2	......	.50	......	......	......	......	8,490	15,290
Do..................	9580	SW.	15	18 N.	6 E.	186	4.5	As received...	6.0	11.8	66.3	15.9	.43	......	......	......	......	6,625	11,930
								Air dried......	1.6	12.4	69.4	16.6	.45	......	......	......	......	6,940	12,490
								Dry coal......	......	12.6	70.5	16.9	.46	......	......	......	......	7,055	12,700
								Pure coal......	......	15.1	84.9	......	.55	......	......	......	......	8,490	15,280
Melmont at Melmont, washed coal.	9575	....	22	18 N.	6 E.	187	6.2	As received...	7.0	20.5	53.7	18.76	.34	4.78	63.00	1.58	11.54	6,300	11,340
								Air dried......	.9	21.8	57.3	20.00	.36	4.36	67.16	1.68	6.44	6,720	12,090
								Dry coal......	......	22.0	57.8	20.18	.37	4.30	67.78	1.70	5.67	6,780	12,200
								Pure coal......	......	27.6	72.4	......	.46	5.39	84.91	2.13	7.11	8,495	15,290
Melmont at Melmont, composite sample.	10412	....	15	18 N.	6 E.	187	4.5	As received...	5.8	12.6	64.6	17.04	.38	4.10	68.59	1.67	8.22	6,540	11,780
								Air dried......	1.4	13.1	67.7	17.85	.40	3.77	71.82	1.75	4.41	6,850	12,330
								Dry coal......	......	13.3	68.6	18.09	.40	3.67	72.83	1.77	3.24	6,945	12,500
								Pure coal......	......	16.2	83.8	......	.48	4.48	88.91	2.16	3.97	8,480	15,260

Melmont at Melmont, No. 1 bed.	9577	SE.	16	18 N.	6 E.	186	7.8	As received	9.2	9.4	63.7	17.7	.66	....	....	....	....	6,180	11,130
								Air dried	1.5	10.2	69.1	19.2	.72	....	....	....	....	6,705	12,070
								Dry coal	....	10.3	70.2	19.5	.73	....	....	....	....	6,810	12,260
								Pure coal	....	12.8	87.2	....	.91	....	....	....	....	8,455	15,220
Fairfax at Fairfax, No. 3 bed.	9607	NW.	26	18 N.	6 E.	188	1.3	As received	1.9	23.3	64.5	10.31	.53	5.00	77.18	2.13	4.85	7,625	13,720
								Air dried	.6	23.6	65.4	10.45	.54	4.92	78.20	2.16	3.73	7,725	13,900
								Dry coal	....	23.7	65.8	10.51	.54	4.88	78.67	2.17	3.23	7,770	13,990
								Pure coal	....	26.5	73.5	....	.60	5.45	87.91	2.42	3.62	8,685	15,630
Fairfax at Fairfax, No. 7 bed.	9608	NW.	26	18 N.	6 E.	188	2.2	As received	2.8	18.5	45.4	33.26	.47	3.90	53.81	1.53	7.03	5,315	9,570
								Air dried	.6	18.9	46.5	34.01	.48	3.74	55.02	1.56	5.19	5,435	9,790
								Dry coal	....	19.0	46.8	34.22	.48	3.69	55.37	1.57	4.67	5,470	9,850
								Pure coal	....	28.9	71.1	....	.73	5.61	84.17	2.39	7.10	8,315	14,970
Fairfax at Fairfax, Blacksmith bed.	9609	NW.	26	18 N.	6 E.	188	2.0	As received	3.3	21.0	63.0	12.72	.68	4.89	73.14	1.89	6.68	7,255	13,050
								Air dried	1.4	21.4	64.2	12.98	.69	4.77	74.63	1.93	5.00	7,400	13,320
								Dry coal	....	21.7	65.1	13.16	.70	4.68	75.66	1.96	3.84	7,505	13,500
								Pure coal	....	25.0	75.0	....	.81	5.39	87.12	2.26	4.42	8,640	15,550
Fairfax at Fairfax, washed coal.	9574	SW.	26	18 N.	6 E.	189	2.9	As received	3.5	22.6	64.4	9.55	.44	5.02	76.17	2.05	6.77	7,510	11,520
								Air dried	.7	23.2	66.3	9.84	.45	4.84	78.45	2.11	4.31	7,735	13,920
								Dry coal	....	23.4	66.7	9.90	.46	4.80	78.95	2.12	3.77	7,785	14,010
								Pure coal	....	26.0	74.0	....	.51	5.33	87.63	2.35	4.18	8,640	15,550
Montezuma, 1 mile south of Fairfax, No. 1 bed.	9602	NW.	2	17 N.	6 E.	190	5.0	As received	5.7	19.2	62.4	12.7	.97	....	....	....	....	7,025	12,640
								Air dried	.7	20.2	65.7	13.4	1.02	....	....	....	....	7,395	13,310
								Dry coal	....	20.4	66.1	13.5	1.03	....	....	....	....	7,445	13,400
								Pure coal	....	23.6	76.4	....	1.19	....	....	....	....	8,610	15,500
Montezuma, 1 mile south of Fairfax, No. 2 bed.	9603	NW.	2	17 N.	6 E.	190	2.3	As received	3.0	18.1	56.2	22.7	.71	....	....	....	....	6,245	11,240
								Air dried	.7	18.5	57.5	23.3	.73	....	....	....	....	6,395	11,510
								Dry coal	....	18.7	57.9	23.4	.73	....	....	....	....	6,440	11,600
								Pure coal	....	24.4	75.6	....	.95	....	....	....	....	8,415	15,150
Montezuma, 1 mile south of Fairfax, washed coal from No. 2 bed.	9604	....	35	18 N.	6 E.	191	5.8	As received	6.7	17.7	54.4	21.16	.73	4.58	61.92	1.77	9.84	6,135	11,040
								Air dried	1.0	18.8	57.7	22.46	.78	4.18	65.73	1.88	4.97	6,510	11,720
								Dry coal	....	19.0	58.3	22.69	.78	4.11	66.40	1.90	4.12	6,575	11,840
								Pure coal	....	24.6	75.4	....	1.01	5.32	85.89	2.46	5.32	8,505	15,310
Montezuma, 1 mile south of Fairfax, No. 3 bed.	9605	NW.	2	17 N.	6 E.	190	3.3	As received	4.0	18.1	58.5	19.4	.49	....	....	....	....	6,565	11,810
								Air dried	.7	18.7	60.5	20.1	.51	....	....	....	....	6,790	12,220
								Dry coal	....	18.9	60.9	20.2	.51	....	....	....	....	6,835	12,300
								Pure coal	....	23.7	76.3	....	.64	....	....	....	....	8,565	15,420
Montezuma, 1 mile south of Fairfax, No. 4 bed.	9606	NW.	2	17 N.	6 E.	190	2.0	As received	2.6	21.0	65.6	10.8	.56	....	....	....	....	7,455	13,420
								Air dried	.6	21.5	66.9	11.0	.57	....	....	....	....	7,605	13,690
								Dry coal	....	21.6	67.3	11.1	.57	....	....	....	....	7,650	13,770
								Pure coal	....	24.3	75.7	....	.62	....	....	....	....	8,600	15,480

Analyses of coal samples from the State of Washington—Continued.

Pierce County—Continued.

Name of mine or form of exposure.	Laboratory No.	Location. Quarter.	Location. Section.	Location. Township.	Location. Range.	Page.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Heat value. Calories.	Heat value. British thermal units.
Montezuma, 1 mile south of Fairfax, washed coal from Nos. 3 and 4 beds.	9613	....	35	18 N.	6 E.	191	4.7	As received...	5.4	19.8	62.4	12.38	0.51	4.94	71.79	2.03	8.35	7,160	12,880
								Air dried......	.7	20.8	65.5	12.99	.54	4.64	75.33	2.13	4.37	7,510	13,520
								Dry coal......	....	21.0	65.9	13.08	.54	4.59	75.85	2.14	3.80	7,565	13,610
								Pure coal......	....	24.1	75.9	....	.62	5.28	87.26	2.46	4.38	8,700	15,660
Mashel at Ashford........	9885	SW.	22	15 N.	6 E.	192	2.4	As received...	4.0	22.0	36.0	38.04	.68	3.69	46.95	1.27	9.37	4,670	8,410
								Air dried......	1.7	22.5	36.8	38.98	.70	3.50	48.10	1.30	7.42	4,785	8,610
								Dry coal......	....	22.9	37.5	39.63	.71	3.38	48.92	1.32	6.04	4,865	8,760
								Pure coal......	....	38.0	62.0	....	1.18	5.60	81.04	2.19	9.99	8,060	14,510
Do..................	9884	SW.	22	15 N.	6 E.	192	2.6	As received...	4.1	24.4	44.7	26.76	.44	4.31	58.16	1.39	8.94	5,720	10,290
								Air dried......	1.5	25.0	46.0	27.47	.45	4.13	59.71	1.43	6.81	5,870	10,570
								Dry coal......	....	25.4	46.7	27.91	.46	4.02	60.66	1.45	5.50	5,965	10,730
								Pure coal......	....	35.3	64.7	....	.64	5.58	84.15	2.01	7.62	8,275	14,890
Prospect 7 miles east of Ashford.	6486	SW.	20	15 N.	7 E.	198	7.0	As received...	9.4	12.8	51.3	26.5	.37	....	....	....	....	5,250	9,450
								Air dried......	2.6	13.7	55.2	28.5	.40	....	....	....	....	5,645	10,160
								Dry coal......	....	14.1	56.6	29.3	.41	....	....	....	....	5,795	10,440
								Pure coal......	....	19.9	80.1	....	.58	....	....	....	....	8,195	14,750
Thurston County.																			
Hannaford No. 1 at Tono.	9089	SE.	20	15 N.	1 W.	194	16.0	As received...	21.0	33.1	36.7	9.2	0.42	....	....	....	....	4,950	8,910
								Air dried......	5.9	39.5	43.7	10.9	.50	....	....	....	....	5,890	10,610
								Dry coal......	....	42.0	46.4	11.6	.53	....	....	....	....	6,265	11,270
								Pure coal......	....	47.5	52.5	....	.60	....	....	....	....	7,085	12,760
Do..................	9573	SE.	20	15 N.	1 W.	194	7.2	As received...	21.5	31.8	40.7	6.04	.43	6.34	52.61	1.11	33.47	5,095	9,170
								Air dried......	15.4	34.3	43.8	6.51	.46	5.97	56.69	1.20	29.17	5,490	9,880
								Dry coal......	....	40.5	51.8	7.69	.55	5.03	66.99	1.41	18.33	6,485	11,670
								Pure coal......	....	43.9	56.1	....	.60	5.45	72.57	1.53	19.85	7,025	12,640
Do..................	9095	NE.	20	15 N.	1 W.	194	17.4	As received...	23.6	31.0	37.3	8.13	.36	6.19	50.36	1.02	33.94	4,750	8,550
								Air dried......	7.4	37.6	45.2	9.84	.44	5.16	60.97	1.23	22.36	5,750	10,350
								Dry coal......	....	40.6	48.8	10.63	.47	4.68	65.85	1.33	17.04	6,210	11,180
								Pure coal......	....	45.3	54.7	....	.53	5.24	73.68	1.49	19.06	6,950	12,510

Do	9094	SW.	21	15 N.	1 W.	194	16.8	As received	22.2	31.7	37.0	9.1	.35	......	......	......	......	4,755	8,560
								Air dried	6.5	38.2	44.4	10.9	.42	......	......	......	......	5,720	10,290
								Dry coal	......	40.8	47.5	11.7	.45	......	......	......	......	6,115	11,000
								Pure coal	......	46.2	53.8	......	.51	......	......	......	......	6,925	12,460
Do	9096	SW.	21	15 N.	1 W.	194	16.7	As received	22.7	31.0	38.3	8.02	.37	6.19	49.56	1.08	34.78	4,795	8,630
								Air dried	7.2	37.3	45.9	9.63	.44	5.20	59.50	1.30	23.93	5,755	10,360
								Dry coal	......	40.1	49.5	10.37	.48	4.75	64.08	1.40	18.92	6,200	11,160
								Pure coal	......	44.8	55.2	......	.54	5.30	71.49	1.56	21.11	6,915	12,340
Hannaford No. 1 at Tono, car sample, run-of-mine coal.	8752	......	......	......	......	195	6.7	As received	20.2	31.5	39.9	8.44	.52	5.93	52.52	1.06	31.53	5,150	9,280
								Air dried	14.5	33.5	42.9	9.05	.56	5.56	56.29	1.14	27.40	5,520	9,940
								Dry coal	......	39.5	49.9	10.58	.65	4.61	65.83	1.33	17.00	6,460	11,630
								Pure coal	......	44.0	56.0	......	.73	5.16	73.62	1.49	19.00	7,230	13,000
Perth, 3 miles north of Centralia.	9178	......	......	15 N.	2. W.	196	12.4	As received	25.1	32.3	34.0	8.65	.82	6.37	47.26	.91	35.99	4,540	8,170
								Air dried	14.5	36.8	38.8	9.88	.94	5.70	53.95	1.04	28.49	5,180	9,330
								Dry coal	......	43.1	45.4	11.55	1.09	4.77	63.08	1.21	18.30	6,060	10,910
								Pure coal	......	48.7	51.3	......	1.23	5.39	71.32	1.37	20.69	6,840	12,320
Black Bear, 2 miles southeast of Tenino.	9939	SW.	31	16 N.	1 W.	197	6.3	As received	16.0	31.9	28.9	23.19	1.50	5.04	43.44	.73	26.10	4,335	7,800
								Air dried	10.4	34.0	30.9	24.75	1.60	4.63	46.36	.78	21.88	4,625	8,330
								Dry coal	......	37.9	34.5	27.61	1.79	3.88	51.73	.87	14.12	5,160	9,290
								Pure coal	......	52.4	47.6	......	2.47	5.36	71.46	1.20	19.51	7,130	12,830
King, 3 miles southwest of Tenino.	9987	SW.	35	16 N.	2 W.	198	9.5	As received	22.4	33.6	33.0	10.95	2.40	6.04	48.88	.72	31.01	4,875	8,770
								Air dried	14.3	37.2	36.4	12.10	2.65	5.50	54.01	.80	24.94	5,385	9,690
								Dry coal	......	43.4	42.5	14.12	3.09	4.58	63.02	.93	14.26	6,285	11,310
								Pure coal	......	50.5	49.5	......	3.60	5.33	73.38	1.08	16.61	7,315	13,170

Proximate analyses of coal samples from Whatcom and Skagit counties, Wash.

[Analyzed by Bureau of Equipment of the Navy Department, Washington, D. C.]

Place.	Condition of sample.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.
Blue Canyon, T. 35 N., R. 5 E.	As received	0.310	22.265	62.395	14.885	0.1[illegible]
Cokedale, Fairhaven:						
T. 35 N., R. 5 E.	do	2.980	35.030	59.980	2.010	.2[illegible]
T. 37 N., R. 4 E.	do	1.790	31.479	62.744	3.679	.3[illegible]

DETAILED DESCRIPTIONS OF MINES, SAMPLES, AND COALS.[1]

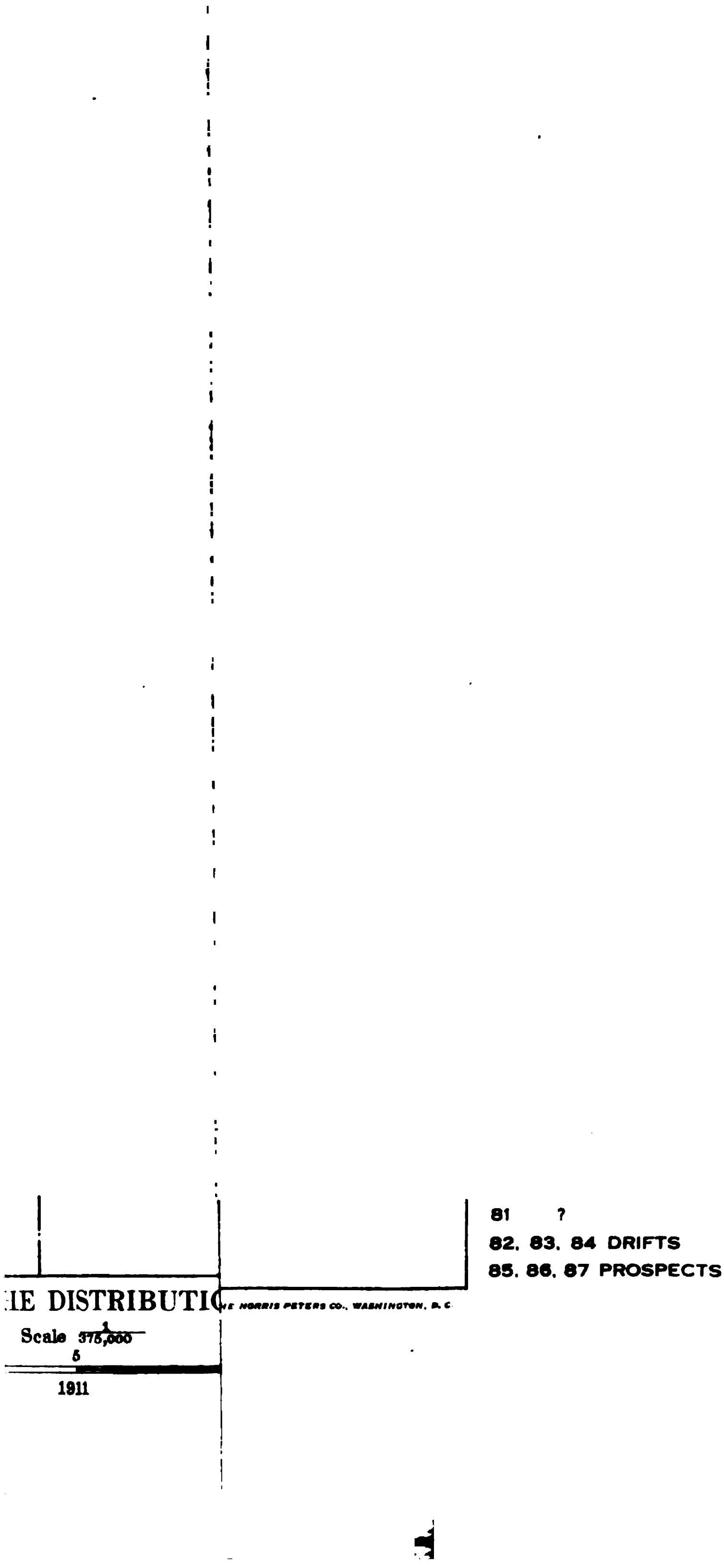
DISTRIBUTION OF MINES.

The general distribution of the mining districts and the locations of the mines and prospects from which samples were obtained are shown on the accompanying map (Pl. III), which is based on the General Land Office map of the State with corrections and additions from the topographic atlas sheets of the United States Geological Survey. The numbers of the mines and prospects refer to the numbers in the list of mines and prospects given at the edge of the map. The system of railroads shows the connections between mines, centers of consumption, and tidewater shipping points.

ORDER OF DESCRIPTION.

It has been the custom in reports on the coal of the State to group the mines according to the counties in which they occur, and the county will be the unit used in the publications contemplated by the State Geological Survey. Therefore the mines and the samples are here arranged and discussed in the same manner, the counties being considered in alphabetic order. The mines and prospects in Kittitas County have been discussed from west to east, in Pierce County from north to south, in Lewis County from east to west, and in Thurston County from south to north. Those in King County are arranged nearly in the order of a rude circle beginning near Grand Ridge and passing through Renton, Black Diamond, Bayne, and Taylor to Snoqualmie. The parts sampled are indicated in the section by an asterisk (*), a dagger (†), or by the insertion of the sample number.

[1] Samples were taken from all the working mines in the State except those at Park, Whatcom County, and at Kopiah, Lewis County. The Blue Canyon mine of the Whatcom County Coal Co. at Park has been in operation for many years. This coal has been repeatedly analyzed and its character is well known. A visit to the mine of the Wilson Coal Co. at Kopiah was made by the writer, but admission to the mine was refused. In Cowlitz County there are several small mines which the writer was unable to visit and sample because the funds available for this investigation were exhausted. Considerable development work has been done at different periods in Skagit County, but no mines are at present in operation there because of the great number of faults and the lenticular character of the coal beds.


81 ?
82, 83, 84 DRIFTS
85, 86, 87 PROSPECTS
IE DISTRIBUTIO
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5
1911

CLALLAM COUNTY.

The coal fields of Clallam County were studied by Ralph Arnold in 1904 and are described by him in two reports.[1]

The only mine at present operating is situated in the Clallam Bay field east of the town of Clallam. Most of the work being done at the time of the writer's visit was for the purpose of development. The analysis given by Arnold of the coal from Clallam was probably that of a sample taken from another bed than that which is mined at the present time. The sample collected by the writer was obtained in February, 1910.

FUCA.

Fuca, a drift mine 6 miles east of Clallam on the shore of the strait of San Juan de Fuca. No. 1.[2]

Operator: Clallam Coal Co., Seattle, Wash.

Kind of coal: Bituminous.

Coal beds.—Several coal beds are reported as occurring in this vicinity, but only one is being developed. An exposure higher on the hill but on a bed underlying the one now being mined is reported, but it was not sampled. The beds strike nearly north and south and dip about 60° W. The bed now being mined, believed to be the middle one of the three referred to by Arnold in his reports, occurs in conglomerate containing pebbles up to 1 inch in diameter. The mine is situated on the face of a very steep sea cliff which rises sharply from the water's edge to a height of about 400 feet. The entrance to the mine is about 50 feet above low tide. The gangway has been driven on the strike of the bed to a distance of about 450 feet. A small fault was encountered which offset the bed a few feet. Practically all the coal between the level of the gangway and the surface has been worked out. The bed varies in thickness from 1 foot 6 inches to 2 feet 6 inches, the average being about 1 foot 10 inches. At several places in the mine lenses of coal from 5 to 50 feet long and varying up to 2 feet in thickness have been found beneath the main bed and separated from it by several inches of shale. The coal bed is so thin that a large amount of rock work is necessary. In the gangway about 4 feet of the roof is brushed down for head room. The following section was measured where the sample was obtained:

Section of coal bed in Fuca mine.

No. 10030.

	Ft.	In.
Sandstone.		
Shale		2½±
*Coal	1	11
Shale	{to 2	7
Sandstone.		
Coal bed	1	11

[1] Coal in Clallam County, Wash.: Bull. U. S. Geol. Survey No. 260, 1905, pp. 413–421; Geological reconnaissance of the coast of the Olympic Peninsula, Washington: Bull. Geol. Soc. America, vol. 17, 1906, pp. 451–468, pls. 55–58.

[2] Numbers refer to location on the map, Pl. III.

Preparation for market.—A bunker of 100 tons capacity has been erected at the entrance to the mine. (See Pl. IV, *A*.) It extends over the water at high tide about 40 feet, and the coal can be loaded from it into barges when the water is not too rough. The coal is passed over 1-inch and ½-inch bar screens. The oversize from the larger screen is hand-picked to remove "sulphur" balls and slate from the roof and floor, and the undersize is washed in a home-made jig to remove the fine shale produced in mining.

Sample for analysis.—Sample 10030 was taken at a point about feet above the gangway in chute 6, about 400 feet from the entrance of the mine. The sandstone both above and below the coal bed is massive and very resistant and makes an excellent roof and floor. The shale immediately overlying the coal does not adhere to it and does not come down in mining; the shale underlying the coal is used as a "mining" [1] and must be separated from the fine coal by picking and washing. The analysis of this sample is given on page 41.

Character and quality of the coal.—The coal is pitch black, very hard, and brittle, and has a vitreous luster. It is massive and laminated and breaks with an irregular splintery and conchoidal fracture. Although it contains nearly as much moisture as subbituminous coal, it gives off little on exposure to the air and hence does not air slack. It contains about the same amount of ash as the subbituminous coal of Renton and Coal Creek. The percentage of sulphur is higher than in any of the other coals described in this report, owing to the occurrence of many minute lenses of marcasite or pyrite disseminated through the main mass of the coal. The bed contains many nodules of pyrite, from 1 inch to several feet in length, which can be readily separated from the coal by picking and washing. The amount of sulphur in the coal in different parts of the bed varies considerably, according to the relative abundance or scarcity of the larger pyrite nodules. In many places the amount of sulphur in the coal may be as low as 2 per cent, and elsewhere as high as 10 per cent. It will be noticed from the analysis that the percentage of fixed carbon is considerably less than that of the volatile matter, the actual ratio of the two being about 9 to 10, a proportion suggestive of that which characterizes cannel coal. A splinter of the coal can be ignited with a match about as readily as cannel from the eastern part of the United States. The coal is different in its characteristics from any other coal in the State or any other coal with which the writer is familiar. Although it resembles subbituminous coal in moisture content and heating value, it should be classed as bituminous coal on account of its ability to stand transportation without disintegration.

[1] "Mining" is a term used in coal mining to indicate a soft layer on which work is begun in opening a bed.

A. BUNKER OF THE CLALLAM COAL CO., AT FUCA, CLALLAM COUNTY, AT LOW TIDE.

B. EXPOSURES OF BEDS OF ANTHRACITE ON SUMMIT CREEK, LEWIS COUNTY.

COWLITZ COUNTY.

The coal fields of Cowlitz County are not very well known on account of the dense surface covering and the scanty outcrops. Coal has been reported at several places along the Northern Pacific Railway in the western part of the county, especially in the vicinity of Castle Rock and Kelso, and several small mines, opened to supply local trade, have been operated periodically for several years. The location of some mines and prospects and a short discussion of the geology of the district has been given by Henry Landes.[1]

In 1904, J. S. Diller[2] visited a mine (No. 81) on Coal Creek 12 miles west of Kelso, a few miles from a slough leading to Columbia River. The following description is taken from his report:

The coal bed is 6 to 7 feet in thickness, with two small partings of sand. The top bench has 12 to 18 inches of bony coal, the middle bench 2½ feet of better quality, and the lower bench 18 inches of coal in part good. The coal bed is overlain by soft sandstone.

In the mine the coal looks bright, but on exposure it loses its luster, cracks somewhat, and partially slacks. Some part of it is well banded and contains small pieces of fossil resin.

Two specimens were taken for analysis, one from the middle (No. 6760) and the other (No. 6761) from the lower bench.

[The analyses of these samples as made in the United States Geological Survey laboratory by W. T. Schaller are given on page 41.]

Mr Schaller reports that—

"The bottle containing No. 6761 was broken when received at the laboratory. A moisture determination of the coarsely ground sample gave 17.79 per cent, showing that the coal had lost moisture in transit, due to the bottle being broken. For this reason no data are given for the coarsely ground No. 6761 sample.

An aluminum sulphate occurs on the joint planes of 6761. The values for volatile combustible matter, fixed carbon, and ash in the coarsely ground No. 6760 are calculated from the corresponding figures of the finely ground sample."

The high percentage of water, ash, and sulphur present are all against its utility. The coal was used in running the engine of the mine and appeared to burn well, but as to later developments in the mine no information is at hand.

The bed of coal is interstratified with a lot of shales and shaly sandstones well exposed along Coal Creek near the mine. The strike of these beds near the mine is northwest-southeast, with a dip of about 15° SW., and it seems probable that if the coal on trial proves of sufficient value to work it could be traced to higher ground where gravity would be of greater service in operating the mine. There are igneous rocks cutting the coal-bearing beds in that region and the strata are faulted locally, but neither igneous rocks nor faults were seen near the mine.

To judge from the above description of the coal it resembles the lower grade of coal in the vicinity of Centralia and Chehalis, in Lewis County, although it is considerably higher in its sulphur content.

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[1] Landes, Henry: Ann. Rept. Washington Geol. Survey, vol. 1, 1901, pp. 279-281; vol. 2, 1902, pp. 255-257.

[2] Diller, J. S., Coal in Washington near Portland, Oreg.: Bull. U. S. Geol. Survey No. 260, 1905, pp. 411-412.

KING COUNTY.

GENERAL DESCRIPTION.

The extent of the coal fields of King County is not well known. The surface is covered by dense timber and undergrowth (Pl. V) and by gravel and glacial drift (Pl. VI, *A*) so that it is very difficult to trace the outcrops of the formations (Pl. VI, *B*), and the character of the rocks is so variable and the quality of the coal so different within short distances that it is almost impossible to correlate coal beds on these criteria. Variations in quality of the coal from subbituminous to bituminous are regional rather than local, except where the beds have been altered by volcanic action. No coal bed so far as known can be said to be subbituminous in one part of a field and bituminous in another part. Both bituminous and subbituminous beds are constant in character within the fields in which they are known to occur, but variations in the character of coal of adjoining fields believed to be closely associated are often very marked. It is believed that the detailed work performed by the State Geological Survey during the summer and autumn of 1909 will do much toward establishing the correlation of the beds in different parts of the county.

The samples taken from this county were collected at different times between July, 1909, and January, 1910, but mostly during the months of July, August, and September. Several samples obtained by other collectors from the mines at Renton, Taylor, and Ravensdale in the last few years have been analyzed by the United States Geological Survey, and the analyses of these samples are given as a means of comparison with those taken by the writer.

Gas is present in many of the mines of this county. In the mines at Black Diamond it is so abundant as to necessitate the use of safety lamps in all the workings. It occurs in small quantities in the subbituminous coal at Coal Creek, but chiefly in the bituminous coal nearer the main crest of the Cascade Mountains.

PROSPECT NORTH OF ISSAQUAH.

A prospect shaft 3 miles north of Issaquah. No. 2.

Opened by United States Coal Co., Seattle, Wash.

Kind of coal: Subbituminous.

Coal bed.—The coal bed probably belongs to the group of coal beds exposed at the Grand Ridge mine, to the south. It strikes N. 73° E. and dips 79° NW. A shaft has been sunk on the bed to a depth of 53 feet. The following section was measured at the bottom of the shaft.

A. FOREST UNDERGROWTH IN THE COAL DISTRICT NEAR BAYNE, KING COUNTY.

A factor which makes study of the coal-bearing formations of Washington very difficult.

B. TYPICAL FORESTED AREA OF THE PUGET SOUND COUNTRY.

Looking east from Lizard Mountain, near Bayne, King County.

Section of coal bed at United States Coal Co.'s prospect 3 miles north of Issaquah.

No. 9291.

	Ft.	in.
Shale, carbonaceous.		
*Coal	3	1
Clay, white, plastic		2
*Coal	2	9
Clay, yellowish, white, plastic		3
*Coal, bony		3½
Shale, slaty, carbonaceous.		
	6	6½

Sample for analysis.—Sample 9291 was taken at the bottom of the shaft. The two clay partings in the bed can be easily separated from the coal and were not included in the sample. The hanging wall and the foot wall of the bed, which are made up of carbonaceous shale, are firm and strong and do not mix with the coal. The analysis of the sample is given on page 41.

Character and quality of the coal.—The coal is grayish black and banded and has a splintery fracture. It contains a small amount of gas which could be heard escaping from the bottom of the shaft. The coal contains a large amount of moisture and probably weathers rapidly on exposure to the direct rays of the sun, but large blocks exposed to the air under the cover of trees for several months showed no signs of breaking down. The coal has about the same heating value as the coal from the mines at Grand Ridge and Issaquah.

GRAND RIDGE.

Grand Ridge slope mine, on the Northern Pacific Railway, 3 miles east of Issaquah. No. 3.

Operator: Central Coal Co., Seattle, Wash.

Kind of coal: Subbituminous.

Coal beds.—Five coal beds are being worked, ranging from No. 1, at the bottom, to No. 7, at the top. They strike N. 34° E. and dip 28° NW. Sections of beds Nos. 1, 2, 3, 4, and 7, where the samples were taken, are given below:

Sections of coal beds in Grand Ridge mine, 3 miles east of Issaquah.

No. 8544, bed No. 1.

	Ft.	in.
Shale.		
*Coal	1	3½
Shale		2½
*Coal	1	
Shale		½
*Coal	1	
Shale		1
*Coal	1	8½
Shale		½
*Coal	1	7
Shale.		
	6	11½

No. 11736, bed No. 3.

	Ft.	in.
Sandstone, massive.		
*Coal	1	7
Shale, carbonaceous		3
Clay, white		6
*Coal	1	11
Clay, white		5
Bone and coal	1	2
Shale		4
Sandstone, massive.		
	6	2

Sections of coal beds in Grand Ridge mine, 3 miles east of Issaquah—Continued.

No. 8545, bed No. 2.

	Ft.	in.
Shale.		
Shale and coal in streaks		5
*Coal	2	
*Coal, banded	2	
Shale.		
	4	5

No. 11737, bed No. 4.

	Ft.	in.
Shale.		
Shale, carbonaceous		4
*Coal	3	1
Shale.		
	3	5

No. 11738, bed No. 7.

	Ft.	in.
Sandstone, massive.		
Shale	2	
*Coal	1	6
Clay, white		¼
*Coal	1	5
Clay, white		¼
*Coal	1	7
Clay		5
*Coal, slightly bony		8
Clay		5
Coal, impure		6
Shale, carbonaceous		11
Shale.		
	9	5½

Preparation for market.—At the time this mine was examined by the writer beds Nos. 1 and 2 only were being worked on a commercial scale. The coal from both beds was mixed in the bunkers; that which passed over 1½-inch bar-screens was hand picked and sold as lump, and that which passed through the screen was washed in a Jeffery-Robinson washer.

Samples for analysis.—Sample 8544, from bed No. 1, was taken from the north end of the north gangway on the first water level about 220 feet north of the rock tunnel to bed No. 2. At this point four distinct shale partings ranging from half an inch to 2½ inches are present. By careful picking and washing these bands may be separated from the coal, and they were therefore excluded from the sample. Both hanging and foot walls are fairly strong and do not mix with the coal in mining. Sample 8545, from bed No. 2, was taken from the north end of the north gangway on the first water level about 100 feet north of rock tunnel from bed No. 1. Both hanging and foot walls are firm and do not mix with the coal. Sample 11736, from bed No. 3, was taken from the left side of chute 4. Sample 11737, from bed No. 4, was taken on the north side of the rock tunnel. This sample was damp when it was sealed in the can. The location of sample 11738 is not given, but it is reputed as being wet when it was sealed in the can.

In preparing sample 9883, 40 pounds of coal which had just passed through the washer and was still wet was taken from the surface of a 50-ton bin. The fragments were reduced to a uniform size of about three-fourths of an inch and the sample was quartered, opposite quarters being rejected and the remainder ground in a bone grinder to the size of a pea. This was in turn quartered by the usual method until the final sample, about a quart, was obtained. This sample was sealed without drying in an air-tight can and mailed to the

A. GLACIAL BOWLDERS ON THE SOUTH BANK OF GREEN RIVER NEAR FRANKLIN, KING COUNTY.

B. EXPOSURES OF THE PUGET FORMATION, IN WHICH THE COAL OCCURS, ALONG GREEN RIVER NEAR FRANKLIN.

chemical laboratory. The analyses of the samples are given on page 42.

Character and quality of the coal.—The coal is grayish black and has a reddish-brown streak. It is banded and laminated and breaks with an irregular splintery fracture. It slacks slightly when exposed to the direct rays of the sun, but does not contain enough moisture to cause it to slack noticeably when shipped in closed cars. Coal from bed No. 1 compares very favorably with that from Coal Creek and Renton. Coal from bed No. 2 is higher in ash than that from bed No. 1 because of the slightly bony nature of the lower portion of the bed, and hence has a lower heating value. The analysis of the washed coal (laboratory No. 9883) represents the quality of a mixture from the two beds. The great amount of moisture in the washed coal as received is due to water from the washing. The coal makes a good fire in stationary boilers without forced draft and is classed as subbituminous.

ISSAQUAH.

Issaquah slope and drift mine, at Issaquah, on the Northern Pacific Railway. No. 4.

Operator: Issaquah Coal Co., Seattle, Wash.

Kind of coal: Subbituminous.

Coal beds.—Only two of the numerous coal beds worked by this company were exposed so that samples could be taken. The company ceased operations at the mine several years ago (see Pl. VII, *A*), and most of the workings were flooded with water so that the samples had to be taken above the water level of the valley. The beds strike N. 74° E. and dip 26° NW. The following sections were taken where the samples were obtained:

Sections of coal beds in Issaquah mine.

No. 8542, bed No. 4.

Shale.	Ft.	in.
*Coal		11½
Shale		½
*Coal	1	
Shale		½
*Coal		5
Shale with streaks of coal		1
*Coal		7
Shale		½
*Coal	1	9
	4	11

No. 8543, bed No. 5.

Sandstone.	Ft.	in.
*Coal	1	
Clay		5
*Coal	2	
Clay		2½
*Coal		11
Shale, carbonaceous		7
Sandstone, white.		
Coal bed	4	6½

Preparation for market.—The coal from this mine was passed over bar screens, after which the lump coal was picked by hand and the screenings were washed in a Jeffery-Robinson tub washer.

Samples for analysis.—Sample 85[illegible] was taken from the side of a small entry west of the main slope on bed No. 4, 50 feet down the slope from the entrance to the mine. All the partings of the bed can be separated from the coal by careful picking and washing and were therefore not included in the sample. Although it had been exposed to the weather for a considerable length of time, the roof appeared to be firm and strong. The bottom of the bed was not exposed, and the character of the floor could not be determined. Mud carried down by water from the overlying rocks had filled the joints in the coal and in order to remove this mud the sample was thoroughly washed in a small stream before being ground and quartered. It was sealed in the can without being dried and for this reason the percentage of moisture in the sample as received is higher than it would be when mined under ordinary conditions. Sample 8543 was taken at the end of a 700-foot water-level gangway on bed No. 5. Both clay partings in the bed can be separated by picking and washing and consequently were not included in the sample. The sample which was taken near the surface and was wet by seepage from overlying rocks and soil was still moist when sealed in the can and the analysis of the sample as received shows moisture of more than ordinary amount. The analyses of these samples are given on pages 42–43.

Character and quality of the coal.—The coal is grayish brown, has a slightly banded structure, and breaks with a conchoidal fracture. It slacks slightly when exposed to the direct rays of the sun but does not contain enough moisture to cause it to weather when shipped in closed cars. Its heating value is about the same as that of the coal from the Grand Ridge mine but is slightly lower than that of the coal from Coal Creek. This coal is classed as subbituminous.

SUPERIOR.

Superior drift mine, 1½ miles southwest of Issaquah, on a spur of the Northern Pacific Railway. No. 5.

Operator: Superior Coal & Improvement Co., Seattle, Wash.

Kind of coal: Subbituminous.

Coal beds.—One coal bed is worked in this mine. It strikes N. 70° E. and dips 30° NW. Another bed, about 300 feet to the north, is thought to be the same as the bed No. 0 at the Issaquah mine. The following sections were measured at the points from which the samples were taken:

Sections of coal beds at Superior mine, 1½ miles southwest of Issaquah.

No. 8548, main bed.	Ft.	in.
Coal, roof.		
Clay (small lens)		2½
*Coal, poor	3	7
Sandstone, shaly, very hard (varies 1″ to 3½″)		2½
*Coal	3	
Coal, floor.	—	—
Total worked	6	9½

No. 8547, bed No. 0.	Ft.	in.
*Coal	1	5
Clay, brown		1
*Coal	1	1
Clay, yellow		4
*Coal		8½
Total worked	3	7½

A. ABANDONED BUNKER OF THE ISSAQUAH COAL CO., AT ISSAQUAH, KING COUNTY.

B. WASHER AND BUNKER OF THE PACIFIC COAST COAL CO, AT BURNETT, PIERCE COUNTY.

Preparation for market.—Temporary bunkers have been erected. The coal is being picked by hand, pending the further development of the mine.

Samples for analysis.—Sample 8548 was taken on the first water level 900 feet from the entrance to the mine and 60 feet up the rise on the west side of the last entry. A parting which occurs near the center can be removed by picking and washing and was therefore not included in the sample. The roof of the mine is coal, but it is separated from the bed at this particular place by small lenses of clay which come down in mining and which must be removed from the coal. The bottom of the bed was not exposed, and the floor at this point was in coal. The sample contained films of mud in the joints of the coal and these were removed by washing before the sample was ground and quartered. The sample was sealed in the can while wet and the analysis of the sample as received contains a slightly excessive amount of moisture. Sample 8547 was taken 60 feet from the entrance of the 75-foot drift on coal bed No. 0. Both partings can be separated from the coal by picking and they were not included in the sample. The coal was slightly moist when taken from the mine and sealed in the can, and for this reason the amount of moisture in the sample as received is a little too high. Analyses of these samples are given on page 43.

Character and quality of the coal.—The coal from these beds is grayish black, gives a brown streak, and is very slightly banded. It breaks with a conchoidal fracture. The upper bench of the main bed is considerably more banded than the others and probably contains a higher percentage of ash. Although the coal weathers slightly on exposure to the sun, it should stand transportation for some distance in closed cars. Its heating value is about the same as that of the coal from Issaquah and Grand Ridge and is somewhat lower than the average of that mined at Coal Creek.

FORD AND BAGLEY.

Ford slope mine and Bagley water-level drift, at Coal Creek, on the Columbia & Puget Sound Railroad. No. 6.

Operator: Pacific Coast Coal Co., Seattle, Wash.

Kind of coal: Subbituminous.

Coal beds.—Five coal beds are worked at present in these mines—the Muldoon, No. 3 and No. 4 beds, in the Ford mine, and the Bagley, Nos. 1 and 2 beds, in the Bagley mine. The beds strike N. 78° W. and dip 36° to 43° NE. The beds are very irregular and the thickness and number of the partings differ considerably in sections measured only a short distance apart. The distances between the beds or the benches in the beds are not at all similar in the opposite ends of the workings. The layer of bony coal overlying bed No. 3, about 700 feet east of the cross tunnel from the Muldoon, is 1 foot 5 inches thick.

Half a mile to the east this layer is about 30 feet thick. The layer of bony shale which separates the upper and lower benches at the same place thickens from 8½ inches to 1 foot 6 inches in a distance of 600 feet to the east. Near the west end of the old workings this parting increases in a short distance from a few feet to nearly 90 feet at the entrance to the old New Castle mine. The following sections were measured where the samples were taken:

Sections of coal beds in Ford mine.

No. 9163, Muldoon coal bed.

	Ft.	in.
Shale, compact (roof).		
Shale.		
*Coal, bony		1
*Coal	2	2
Shale, gray-brown		1
*Coal		8
Shale, gray-brown, streaks of coal		2½
*Coal		8
Shale, brown at center, grades to coal each way		5
*Coal	1	8½
"Sulphur" band		1
Shale, soft, slacks		1½
Shale, compact.		
	6	2½

No. 9165, Muldoon coal bed.

	Ft.	in.
Shale, compact, scales off.		
Shale, carbonaceous		1
*Coal		10
†Coal, bony		1
*Coal		6
Bone, sandy		½
*Coal		9½
Shale, slate-colored		1
*Coal		7
Shale, slate-colored		2½
*Coal		6
Coal, bony		1
Shale, brown, carbonaceous		2
Coal, bony		1
*Coal	1	
*Shale, clayey		½
*Coal	1	
Coal, bony.		
	6	1

No. 9164, lower bench of bed No. 3.

	Ft.	in.
Shale, hard black.		
*Coal	1	9½
Shale, black, carbonaceous.		
	1	9½

No. 9166, Muldoon coal bed.

	Ft.	in.
Shale, compact (good roof), slate-colored.		
Shale, black, carbonaceous		1
*Coal		8
*Coal, bony		2
*Coal		5
*Clay, "sulphur" band		¼
*Coal		10
Shale, brown (clayey)		1
*Coal		5
Shale, brown		1
*Coal		6½
Shale		3
*Coal		9½
*Shale and bone		½
*Coal	1	
Shale, carbonaceous, black to brown.		
Shale (good bottom).		
	5	4¾

No. 9168, upper bench of bed No. 3.

	Ft.	in.
Shale.		
*Coal		8
†Shale, black, carbonaceous		3
*Coal	2	1
*Coal, bony		¼
*Coal		3½
Coal, bony		½
*Coal		8
Shale, brown		½
*Coal		7
Shale, hard black.		
	4	7¾

No. 9167, bed No. 4.

	Ft.	in.
Sandstone, white, shaly.		
Shale, brown, carbonaceous		1
*Coal		8½
Shale, yellow-brown		1
*Coal		2½
Coal, bony		2
*Coal		2½
*Coal	1	9
*Coal, slightly bony, soft		2½
*Coal	1	5
Shale, yellowish brown.		
	4	10

Sections of coal beds in Bagley mine.

No. 9170, Bagley No. 1 bed.

	Ft.	in.
Shale, brown, carbonaceous.		
*Coal, banded	1	3
Shale, brown, carbonaceous		1
*Coal, banded	1	3½
Shale, yellow		½
*Coal		6½
Shale, brown		½
*Coal, bony		3
Shale, brown		½
*Coal		11½
Shale, brown, "sulphur"		½
*Coal		5½
Shale, hard.		
	5	

No. 9169, lower bench of Bagley No. 2 bed.

	Ft.	in.
Shale, hard, carbonaceous.		
*Coal	1	7
†Shale, soft, very carbonaceous		1
*Coal	2	5
Shale, carbonaceous (fair bottom).		
	4	1

No. 9171, upper bench of Bagley No. 2 bed.

	Ft.	in.
Sandstone, white (good roof).		
Shale, carbonaceous		½
*Coal		7
Shale, carbonaceous		6
*Coal		3½
*Coal, badly crushed		½
*Coal		5½
Shale, hard, nearly black		1
*Coal, bony		2½
Shale, sandy, "sulphur" band		½
*Coal, bony, with streaks of shale		5
Shale, brown to yellow.		
Coal bed.	2	7½

Preparation for market.—The coal from all the beds is passed over a 2½-inch bar screen at the bunkers. The oversize is picked by hand for steam and domestic coal. The undersize is washed in a Jeffery tub washer.

Samples for analysis.—Sample 9163 was taken from the Muldoon bed at the east end of the first air course above the gangway on the first level, about 5,400 feet east of the slope. The bed contains three partings, which can be separated by careful picking and washing, and these partings were not included in the sample. A thin, soft layer of bony coal and shale between the upper bench of coal and the roof comes down with the coal in mining and is removed by the washer. A band of pyrite and a thin layer of soft shale at the bottom of the lower layer breaks away from the floor and is separated by the washer. Sample 9166 was taken from the first level gangway on the Muldoon bed 5,750 feet west of the slope. The bed contains numerous thin partings, of which only parts can be separated from the coal by picking and washing. In order to obtain a representative amount of ash, three of the partings were omitted from the sample. A thin layer of carbonaceous shale occurs between the coal and the roof and another between the coal and the floor. Both of these mix with the coal in mining and must be removed at the bunker. Sample 9165 was taken from the first level gangway on the Muldoon bed 1,400 feet west of the slope and 80 feet up chute 13½. The bed contains several partings, which generally can be separated from the coal by picking and washing. Half of the upper parting and the entire lowest parting were included in the sample. A thin layer of carbonaceous shale occurs between the top of the bed and the roof. This breaks from the roof in mining and mixes with the coal and must be picked out at the bunker. Sample 9168 was taken from the upper bench of bed No. 3 on the first level gangway 700 feet east of the cross tunnel from the Muldoon bed. The bed contains four partings, the upper three of which can be removed by picking and washing only with difficulty, and in order to obtain a representative amount of ash half of the upper parting and the entire parting next below were included in the sample. Sample 9164 was taken from the lower bench of bed No. 3 at the same location as No. 9168. The lower bench is separated from the upper by 8½ inches of bone, and as both benches are worked together in this part of the mine, the bone separating them must be removed at the bunker. Sample 9167 was taken on the first level gangway on bed No. 4, about 650 feet east of the cross tunnel from the Muldoon. In the upper part of the bed are two partings which can be separated from the coal and were not included in the sample. A thin layer of carbonaceous shale between the coal and the roof and a portion of the floor mixes with the coal in mining and must be removed at the bunker. Sample 9170 was taken from Bagley No. 1 bed on the first water-level gangway at the entrance to the rock tunnel from the Bagley No. 2 to the Muldoon. The bed contains five partings which can be separated from the coal by careful picking and washing, and which were not included in the sample. It is not being worked at the present time. Sample 9171 was taken from the upper bench of the Bagley No. 2 bed, 36 feet up chute 24 of the first water level. Several partings can be separated from the coal, and these were not included in the sample; a thin layer of carbonaceous shale between the bed and the roof breaks down with the coal and must be removed at the bunker. Sample 9169 was taken from the lower bench of the Bagley No. 2 bed at the same place from which sample 9171 was taken. This bench is separated from the upper bench by about 5½ inches of shale. Both benches are worked at the same time and the shale between them must be removed from the coal. A small band of soft shale occurs in the center of this bench. About half of it can be separated during preparation for market, and therefore only half was included in the sample. The analyses of these samples are given on pages 43–44.

Character and quality of the coal.—The coal is grayish-black, has a slightly banded structure, and breaks with an irregular conchoidal fracture. It contains about the same amount of moisture as the coal of Issaquah, Grand Ridge, and Renton. It slacks slightly when exposed to the direct rays of the sun, but will stand transportation for a considerable distance in closed cars. The coal is good for domestic purposes and for steam and stationary boilers without forced draft, and should be classed as a high-grade subbituminous coal.

DENNY-RENTON.

Denny-Renton drift mine, at Renton, on the Columbia & Puget Sound Railroad and Chicago, Milwaukee & Puget Sound Railway. No. 7.

Operator: Denny-Renton Clay & Coal Co., Seattle, Wash.

Kind of coal: Subbituminous.

Coal bed.—The coal bed worked at this mine is known as the Renton No. 1. It overlies the two beds worked by the Seattle Electric Co. at the Renton mine, strikes N. 32° E., and dips 14° SE. The bed is worked in two benches and a sample of each was taken. The following sections were measured at the places from which the samples were obtained:

Sections of Renton No. 1 coal bed in Denny-Renton mine.

No. 9154, upper bench.

	Ft.	In.
Shale, sandy.		
*Coal, slaty		1
*Coal	1	1
Shale		1
*Coal	1	
Shale, hard, carbonaceous	1	6
Coal bed	2	3

No. 9155, lower bench.

	Ft.	In.
Clay, yellow.		
*Coal		11
Shale (clayey)		3½
Coal, bony		5
Coal, bony, shaly toward top		8½
*Coal	1	6
Clay		2½
Coal, bony		3½
Clay, sandy		½
Coal		5
Clay, sandy		1
*Coal	2	1
Clay, plastic, yellow.		
	6	11½

Preparation for market.—The layers between the coal are thick and are separated in the mine, where they are used as gob. The coal as it comes from the mine is picked at the bunker before using.

Samples for analysis.—Sample 9154 was taken from the gangway about 300 feet north of the south line of sec. 17. The upper layer of the bench consists of shaly coal that can be separated only with difficulty from the coal immediately underlying it; this layer and the shale separating the two coal beds were not included in the sample. Sample 9155 was taken at two places on the gangway near the north line of sec. 20. The sample from one part of the bed was taken 540 feet south and 160 feet west of the north quarter corner of sec. 20 and the sample of the other part was taken 120 feet due south of the same corner. This bench contains three good layers of coal, separated by layers of clay and by layers of coal too thin to be mined economically. The two benches of coal are separated by 2 feet 8½ inches of material, which must be removed; the three layers in the lower bench are separated by thick partings, which are thrown into the gob. Several of the layers of clay absorb moisture upon exposure to the air and swell to about 1¼ times their original thickness, making it very difficult to keep the gangways and rooms open. The samples of coal were moist when taken from the mine and prepared for the laboratory, and therefore the percentage of moisture in the sample as received is a little too large. Analyses of these samples are given on page 44.

Character and quality of the coal.—The color of the coal is grayish-black, the streak reddish-brown, and the structure laminated. It breaks with a splintery fracture, which is almost conchoidal. A considerable amount of moisture is present in it and it slacks slightly when exposed to the air. Its heating value is about the same as that of the coal from bed No. 2 and from the upper bench of bed No. 3 at Renton, but is slightly lower than that of the average coal from the lower bench of bed No. 3 and from the Coal Creek mines. It is classed as a subbituminous coal.

RENTON.

Renton slope mine, at Renton, on the Northern Pacific Railway, the Puget Sound Electric Railway, the Columbia & Puget Sound Railroad, and the Chicago, Milwaukee & Puget Sound Railway. No. 8.

Operator: Seattle Electric Co., Seattle, Wash.

Kind of coal: Subbituminous.

Coal beds.—Renton No. 2 and No. 3 coal beds are being worked in this mine. The older workings are on the lower or the No. 3 bed. The beds strike about N. 10° E. and dip 12° SE. The following sections were measured at the places where the samples were taken:

Sections of coal beds in Renton mine.

No. 9158, bed No. 2.

	Ft.	in.
Shale, brown.		
*Coal	2	4
Clay		2½
*Coal	1	5
Shale, brown		7
Coal, bony	1	6
Coal	1	1
Clay		2
Coal, bony		2
Clay		6
Coal, bony		5
	8	4½

No. 9160, lower bench of bed No. 3.

	Ft.	in.
Shale, brown (slightly carbonaceous).		
*Coal		9½
Coal, bony, and carbonaceous shale		5
*Coal	1	9½
Shale, black, carbonaceous.		
	3	

No. 9156, lower bench of bed No. 3.

	Ft.	in.
Shale, black, carbonaceous.		
*Coal	2	8½
Shale, black, carbonaceous.		

No. 9163, lower bench of bed No. 3.

	Ft.	in.
Shale.		
*Coal		10
Shale, hard, black		4
*Coal	1	10
Shale, black, carbonaceous.		
	3	

No. 2455, bed No. 3.

	Ft.	in.
*Coal	2	2
Coal, bony		11½
*Coal		8½
Shale		1½
*Coal		6
Shale		1
Coal, bony		11
*Coal	2	3
	7	8½

Section of coal beds in Renton mine—Continued.

No. 9159, upper bench of bed No. 3.

	Ft.	in.
Sandstone, white.		
Mixture of white clay and brown shale, 0 to 4′ in mine.		
*Coal	2	3½
Shale, brown		1
*Coal		8½
†Shale, brown, carbonaceous		2
*Coal		8
Shale, brown		2½
*Coal		5
Shale, carbonaceous.		
	4	6½

No. 9157, upper bench of bed No. 3.

	Ft.	in.
*Shale, black, carbonaceous		3½
*Coal	3	6½
Shale, brown		3½
*Coal		3½
Shale, black, carbonaceous		1½
	4	6½

No. 9161, upper bench of bed No. 3.

	Ft.	in.
Shale, clayey (heaves).		
*Coal	2	8½
Shale, brown		1
*Coal		2½
Shale, brown		½
*Coal		7
Shale, brown, carbonaceous		½
*Coal	1	2
Shale (heaves).		
	4	10

No. 2456, bed No. 3.

	Ft.	in.
*Coal	2	7
Bone		1
*Coal		9
Bone		2½
*Coal		10½
Bone	1	5
*Coal		6
Bone		4
*Coal	1	4
	8	1

Preparation for market.—On account of the low dip of the beds the larger partings can be separated in the mine. The coal is mined in benches and the larger partings thrown in the gob. At the bunker the coal is passed over a shaking screen with 2-inch and 3-inch perforations. The oversize is picked on the lower end of the screen and on the car. The undersize is washed in a Jeffery tub washer, and is screened and sold as nut, pea, and barley coal.

Samples for analysis.—Sample 9158 was taken from bed No. 2 about 140 feet up the first plane north from the fifth level south. The bed contains one clay parting which can be separated by picking and washing, and this parting was not included in the sample. The roof of the mine is strong, and does not mix with the coal. The coal bed is underlain by several layers of shale and more or less impure coal. These layers are taken up in the main gangways and entries, and the impurities are thrown into the gob or separated at the bunker. Sample 9159 was taken from the upper bench of bed No. 3 on the seventh level, 500 feet north of the main slope. The bed contains several partings, and as it would be difficult to separate the center parting cleanly from the rest of the coal about half of it was retained in the sample. The bed is overlain by a mixture of white clay and brown shale, ranging up to 4 feet in thickness in this part of the mine, which frequently falls with the coal, and is separated and thrown in the gob. Sample 9160 was taken from the lower bench of bed No. 3 at the place from which No. 9159 was taken. The bench contains near the center a layer of bony coal and carbonaceous shale, which is separated in mining and in preparation for the market, and was therefore not included in the sample. The lower bench of the bed is separated from the upper bench by about 1 foot 5 inches of shale, which is separated from the coal and thrown into the gob. Sample 9157 was taken from the upper bench of bed No. 3 at the north end of the gangway of the ninth level north about 2,900 feet east and 1,300 feet north of the main portal of the mine. The bed contains one parting, which can be separated from the coal and was not included in the sample. This bench is separated from the roof by about 3½ inches of carbonaceous shale which comes down with the coal, and must be removed in preparation for the market. Sample 9156 was taken from the lower bench of bed No. 3 at the place where 9157 was taken. It is separated from the upper bench by 1 foot 5 inches of shale, which is removed from the coal during the mining, and is thrown into the gob. The coal in these two samples was slightly moist, owing to the seepage of water from the rocks above, and inasmuch as the samples were not dried before sealing in the cans, analyses show a slightly higher per cent of moisture in the "as received" determination than should be expected in average coal from this part of the mine. Sample 9161, taken from the upper bench of bed No. 3 about 600 feet above the sixth level south on plane No. 6 of the new workings, contains three shaly layers, which can be separated in mining and in preparation for market and which were therefore not included in the sample. A bed of soft shale between the upper bench and the roof absorbs moisture upon exposure to the air and swells to about 1¼ times its original thickness. Sample 9162 was taken from the lower bench of bed No. 3 at the location from which sample 9161 was taken. It contains one layer of bone, which can be removed from the coal and was not included in the sample. This bench is separated from the upper bench by about 3 feet of shale, the upper part of which absorbs moisture when exposed to the air and swells to about 1¼ times its original thickness. Analyses of these samples are given on pages 44–45. The samples noted below were also taken from this mine:[1] Sample 2455 was taken by M. R. Campbell October 9, 1905, from bed No. 3 in the sixth level gangway, 2,400 feet south of the slope. All the partings in the bed were separated from the sample. Sample 2456 was taken at the same time as No. 2455 from the seventh level gangway, 150 feet north of the slope. All the partings in the bed were excluded from the sample. Carload sample 2687 consisted of pea coal from the washer and No. 2686 was made up of run-of-mine coal. These carload lots were sent to the Geological Survey fuel-testing plant at St. Louis in 1905, and the analyses of the samples are included in the table on page 45.

[1] Bull. U. S. Geol. Survey No. 332, 1908, pp. 272–274.

Character and quality of the coal.—The coal is pitch black when freshly fractured, but turns grayish black in a very short time. It has a reddish-brown streak, is slightly banded and laminated, and breaks with a slightly conchoidal splintery fracture. It contains a considerable amount of moisture, and slacks slightly when exposed to the sun, but will stand transportation to a considerable distance when shipped in closed cars. Bed No. 2 and the upper bench of bed No. 3 have a heating value somewhat lower than that of the lower bench of bed No. 3, which is about the same as that of the better grades of coal obtained from the Coal Creek mines. This coal should be classed as high-grade subbituminous.

DANVILLE.

Danville, a water-level mine at Danville, on a spur of the Columbia & Puget Sound Railroad. No. 9.

Operator: North Coast Colliery Co., Seattle, Wash.

Kind of coal: Subbituminous.

Coal bed.—Only one bed is worked at this mine. It strikes N. 42° E. and dips 75° SE. The following section was measured where the sample was taken:

Section of coal bed in Danville mine.

No. 9323.

	Ft.	In.
Shale, hard.		
Shale, rather soft.		
Coal, broken and apparently dirty	1	11
*Coal	2	2½
*Coal, broken and apparently dirty	3	9
Shale, yellow, slightly carbonaceous.		
Coal bed worked	5	11½

Sample for analysis.—Sample 9323 was taken 20 feet to the southwest along the bed from the end of the rock tunnel from the fan. The mine had been abandoned for more than a year and the exposures of the coal along the gangway were very badly caved, so that it was difficult to obtain a good sample. Considerable movement has taken place along the bed, so that it would be difficult to prevent the impure coal overlying that part of the bed sampled from mixing with the better coal. About 7 inches of rather soft shale overlies the upper bench of coal, and a layer of carbonaceous shale underlies the bed. Where these were exposed in the mine they were soft and broken and would mix with the coal in mining. The analysis of this sample is given on page 45.

Character and quality of the coal.—The coal is grayish black, is slightly banded, and breaks with a splintery and conchoidal fracture. It has a relatively large amount of moisture and slacks slightly when exposed to the sun, but will hold up well for considerable length of time when shipped in closed cars. It is a subbituminous coal and has about the same heating value as the coal from the upper bench of bed No. 3 at Renton and the coal from Issaquah and Grand Ridge.

RAVENSDALE NO. 1.

Ravensdale No. 1, slope mine at Ravensdale, on the Northern Pacific Railway. No. 10.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal beds.—Three coal beds are being worked. They are, in ascending order, Nos. 3, 4, and 5. Bed No. 9 has been tapped by a rock tunnel, and a gangway 100 feet long has been driven to determine the character of the coal. All the beds strike approximately N. 45° E. and dip northwest at angles varying between 22° and 40°. Both the main and the auxiliary slope are on bed No. 5, and a rock tunnel about 200 feet long connects No. 5 with Nos. 3 and 4. Beds Nos. 3 and 4 are separated by about 10 feet of carbonaceous shale and impure coal. The sections measured at the places where the samples were taken are as follows:

Sections of coal beds in Ravensdale No. 1 mine.

No. 9266, bed No. 3.

	Ft.	in.
Shale		7+
Coal, bony		4
*Coal (containing "nigger-heads")	2	
"Sulphur"		1
*Coal	2	2½
Shale and bony coal		8½
*Coal		8
Shale		¼
*Coal ("Sulphur" band near center)	2	2½
Shale, hard, carbonaceous		
Coal bed	7	10¾

No. 9270, bed No. 5.

	Ft.	in.
Shale, gray.		
Shale, black, carbonaceous.		
*Coal		3½
*Shale, sandy, brown		½
*Coal		3½
*Shale, brown		¼
*Coal		5
Shale, sandy and bone		2
*Coal	1	1
Bone and bony coal		11
*Coal		2½
Bone		1
*Coal	2	
Clay		1
*Coal (reported to be 3 feet).	2+	
	7	7½

No. 9271, bed No. 5.

	Ft.	in.
Shale.		
*Coal	3	2½
*Coal, bony	1	2½
Shale		6
*Coal	4	2½
Shale, sandy		1
*Coal, dirty	1	5
Shale.		
	10	7½

No. 9273, lower bench of bed No. 5.

	Ft.	in.
Shale.		
*Coal	4	2½
Shale, sandy		1+
*Coal, dirty	1	5
Shale.		
	5	8½+

No. 9267, bed No. 4.

	Ft.	in.
Shale.		
*Coal	3	7
Shale, irregular		½
*Coal	2	
Clay, yellowish white.		
	5	7½

No. 9274, bed No. 5.

	Ft.	in.
Clay, black		7
*Coal	1	
"Sulphur" band and coal.		1
*Coal	1	7
Shale, sandy		1
*Coal		2
Shale		2
*Coal	1	3½
Shale		½
Coal		6+
Coal bed wo[illegible]	4	4½

Sections of coal beds in Ravensdale No. 1 mine—Continued.

No. 9272, upper bench of bed No. 5.

	Ft.	in.
Shale.		
*Coal	3	2½
Coal, bony.		

No. 9277, bed No. 9.

	Ft.	in.
Coal, bony	1	5
*Coal	2	2½
Bone, poor	1	7
Shale, very slightly carbonaceous.	1	7
Shale.		
	6	9½

Preparation for market.—No attempt is made to separate the partings from the coal in the mine. At the bunker the run-of-mine coal is passed over a shaking screen having 2½-inch and ¾-inch perforations. That which passes through the holes is sorted in a revolving screen, and the different sizes are passed through a spiral dry washer, which has not been found very efficient in separating the impurities from the coal. The coal from the spiral separator and from the picking table are mixed in the bunker before shipment. The entire output of the mine is used by the Northern Pacific Railway.

Samples for analysis.—All the samples were collected on the second level. Sample 9266 was taken October 20, 1909, from the face of the east gangway of bed No. 3, 775 feet east and 400 feet north of the center of sec. 36, T. 22 N., R. 6 E. The bed contains three partings, which are nearly regular, and which may be separated from the coal by careful picking and washing. The roof of the mine is poor and in many places breaks down and mixes with the coal. The floor is fairly firm and does not mix very much with the coal. Sample 9267 was taken from bed No. 4 at a point 100 feet up chute 16 of the east gangway. The irregular layer of shale which occurs in the center of the bed and a considerable amount of shale from the roof is mixed with the coal in mining, but these impurities can be removed by careful picking and washing. Sample 9270 was taken from bed No. 5 about 15 feet east of the sump at the bottom of the slope. Only the upper part of the bed was exposed. Two thin partings near the top, which could only be partially separated from the coal by picking and washing, were included in the sample to offset the amount of ash which might be left in the coal from the other partings. Sample 9274 was taken from chute 31 about 20 feet up the rise from the east gangway on bed No. 5. The bed contains three partings, which can be separated from the coal and which were not included in the sample. About 7 inches of black clay overlies the coal and is mixed with it in mining. This clay must be removed in preparation for use. The sample represents the part of the bed being mined in the part of the workings from which the sample was taken. Sample 9271 was taken from bed No. 5, 150 feet up chute 59 on the east gangway. This section represents the entire thickness of the bed. The two shaly partings can be separated in preparation for use and are not included

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ıntery fracture; it may be readily
·al by its slightly banded texture.
ınt of moisture as the McKay and
the sun, but its ash content is some-
. it is a noncoking bituminous coal of

DIAMOND NO. 14.

-lope mine at Black Diamond, on the
.ilroad. No. 13.
oal Co., Seattle, Wash.

·s.

·ds are being worked at this mine. The
e McKay and the upper one as the Little
. . At the surface these beds are separated
and bony coal, but the distance between the
·ly toward the deeper part of the workings.
ıt 3,200 feet down the dip from the surface,
by about 90 feet of sandstone. At the main
. 75° W. and dip 30° SW.; beyond the electric
›f the workings the strike is nearly N. 25° W.
The beds are uniform in thickness through

Character and quality of the coal.—The coal of the lower bench is pitch black in color and has a dark-brown streak. It has a vitreous luster and is massive without any distinct banding. The fracture is irregular and, along the planes of the butt joints, somewhat conchoidal. The coal from the upper bench resembles that of the lower bench except that it is slightly banded. The McKay coal has a relatively small amount of moisture and does not crumble when exposed to the sun. It is noncoking bituminous coal of rather high grade, and compares favorably with many of the noncoking coals from the eastern part of the United States.

MORGAN.

Morgan, slope mine 1 mile northwest of Black Diamond, on the Columbia & Puget Sound Railroad. No. 12.

Operator: Pacific Coast Coal Co., Seattle, Wash.

Kind of coal: Bituminous.

Coal beds.—Two beds, the lower of which is known as the McKay and the upper as the Little or Upper McKay, are being worked in this mine. Near the surface the two beds are separated by about 10 feet of shale and sandstone, but in the lower workings, which are about 3,000 feet down the dip from the surface, the sandstone increases in thickness to nearly 90 feet. The beds strike about north-south near slope, from which point northward the outcrop swings gradually to about N. 20° E. The dip is about 25° W. Both beds are uniform in thickness throughout the workings, and the partings are fairly regular for a considerable distance. The following sections were taken at the places from which the samples were obtained:

Sections of coal beds in Morgan slope.

No. 9106, McKay bed.

	Ft.	in.
Shale.		
*Coal, good, clean, bright	6	
Coal, shaly and bone		1
Coal		2½
Shale.		
	6	3½

No. 9108, Upper McKay bed.

	Ft.	in.
Shale, black.		
*Coal	1	4
Shale, lens		2
*Coal	3	2½
Shale.		
	4	8½

Preparation for market.—No attempt is made to separate any of the partings from the coal in the mine. At the bunker the coal from the two beds is picked over different sets of screens. It is not necessary to pick the coal from the lower bed except to remove pieces of mine timber and fragments which may have broken from the roof and floor; the upper bench is picked more carefully to remove the shale partings which in many places are present in the coal.

Samples for analysis.—Sample 9106 was taken from the McKay bed on the north side of chute 46 about 12 feet above the north gangway on the sixth level. At this point the bed has a very good roof which does not break or become mixed with the coal, but it is underlain by about 3½ inches of shaly coal which sometimes breaks from the floor and must be separated at the bunker. Sample 9108 was taken from the Upper McKay bed on the south side of chute 11, about 15 feet above the north gangway on the sixth level. A lens of shale contained in the bed can be separated from the coal by picking, and was not included in the sample. Analyses of these coals are given on page 47.

Character and quality of the coal.—The coal of the McKay bed is pitch black, has a dark-brown streak, and breaks with an irregular, slightly conchoidal fracture along the lines of the butt joints. Elsewhere the fracture is irregular. It has a vitreous luster and massive structure. The coal contains a small amount of moisture and does not slack when exposed to the sun. Sulphur is present in it in somewhat higher amount than in the coal from the same bed farther east and north. A small amount of gas, which is given off from the coal very slowly, accumulates at the top of the working rooms and makes necessary the use of safety lamps. The McKay bed yields a noncoking bituminous coal which compares very favorably with the better grades of bituminous coal obtained in the Eastern States. The coal of the Upper McKay bed is pitch black and has a dark brown streak and a somewhat splintery fracture; it may be readily distinguished from the McKay coal by its slightly banded texture. It contains about the same amount of moisture as the McKay and does not slack when exposed to the sun, but its ash content is somewhat higher. Like the McKay, it is a noncoking bituminous coal of good quality.

BLACK DIAMOND NO. 14.

Black Diamond No. 14, slope mine at Black Diamond, on the Columbia & Puget Sound Railroad. No. 13.

Operator: Pacific Coast Coal Co., Seattle, Wash.

Kind of coal: Bituminous.

Coal beds.—Two coal beds are being worked at this mine. The lower one is known as the McKay and the upper one as the Little McKay, or Upper McKay. At the surface these beds are separated by about 4 feet of shale and bony coal, but the distance between the two beds increases greatly toward the deeper part of the workings. At the ninth level, about 3,200 feet down the dip from the surface, the beds are separated by about 90 feet of sandstone. At the main slope the beds strike N. 75° W. and dip 30° SW.; beyond the electric slope in the west end of the workings the strike is nearly N. 25° W. and the dip is 30° SW. The beds are uniform in thickness throughout the mine, and the partings and impurities in the beds are fairly continuous. The following sections were measured at the places from which the samples were obtained:

Sections of coal beds in Black Diamond No. 14 mine.

No. 9105, McKay bed.

	Ft.	in.
Shale, brown, sandy.		
* Coal	5	½
* Coal, bony, soft		3
	5	3½

No. 9114, Upper McKay bed.

	Ft.	in.
Shale, brown.		
* Coal, bright, black		11½
Shale, black, carbonaceous.		7
* Coal	2	9½
Shale, black, carbonaceous.		
	4	4

Preparation for market.—No attempt is made to remove any of the partings from the coal in the mine. At the bunker the coal from the two beds is picked over separate screens. It is not necessary to pick the coal from the lower bed except to remove pieces of mine timber and fragments which may have broken from the roof and floor, but the upper bench is picked more carefully to remove the shale partings which in many places are present in the coal.

Samples for analysis.—Sample 9105 was taken from the McKay bed 70 feet from the gangway in chute 59 on the eighth level north. At this place the bed contains a layer of bony coal near the bottom, which is used as a "mining," and which can not be readily separated from the coal without washing. It is believed to be so low in ash that it will not materially decrease the quality of the coal from the remaining part of the bed. Sample 9114 was taken from the Upper McKay bed 20 feet beyond chute 16 on the eighth level gangway north. The bed contains one shale parting which can be separated at the bunker and which was not, therefore, included in the sample. The shales which overlie and underlie this bed are mixed to some extent with the coal and must be removed at the bunker. The analyses of the samples are given on page 47.

Character and quality of the coal.—The coal of the McKay bed is pitch black, has a dark-brown streak, and breaks with a somewhat conchoidal fracture along the lines of minor joints. Except at the joints the fracture is irregular. It is massive and has a vitreous luster. It contains a small amount of moisture and does not slack when exposed to the sun. The amount of sulphur is somewhat higher than that of the same coal farther to the east and north. A small amount of gas is given off from the coal very slowly and accumulates in the abandoned rooms, making necessary the use of safety lamps. The coal is a noncoking bituminous coal and compares very favorably with the better grades of bituminous coal obtained in the Eastern States. The coal of the Upper McKay bed is pitch black, and has a dark-brown streak and a somewhat splintery fracture; it may be readily distinguished from the coal of the McKay bed by its slightly banded texture. It contains about the same amount of moisture as the McKay and does not slack when exposed to the sun, but has a somewhat greater amount of ash. Like the McKay it is a noncoking bituminous coal of good quality.

LAWSON.

Lawson, a slope mine 1 mile northeast of the Black Diamond, on the Columbia & Puget Sound Railroad. No. 14.

Operator: Pacific Coast Coal Co., Seattle, Wash.

Kind of coal: Bituminous.

Coal beds.—The Upper or Little McKay and the McKay proper occur as practically one bed of coal in this mine. Only the McKay is mined, however, except in the gangway, where the upper bed is taken out to give additional space in which to handle the cars. The beds are separated by about 10 inches of hard, black carbonaceous shale, which is used as a roof for the McKay bed throughout most of the workings. The beds strike N. 25° E. and dip 60° SE. at the west end of the workings, and strike N. 69° E. and dip 30° SE. at the east end. The McKay bed is uniform in thickness throughout the mine. The following sections were measured at the places from which the samples were taken:

Sections of coal beds in Lawson mine.

No. 9104, McKay bed.

	Ft.	in.
Shale, black, carbonaceous		11
*Coal	4	9½
Shale, brown, carbonaceous.		
	5	8½

No. 9107, Upper McKay bed.

	Ft.	in.
Shale.		
*Coal with few layers of carbonaceous shale	2	2½
Shale, black, carbonaceous		1
*Coal	1	
Shale, brown, sandy		1
Coal, bony		2½
*Coal	1	2½
Shale, black, carbonaceous		11
Coal bed	5	8½

Preparation for market.—No attempt is made to remove any of the partings from the coal in the mine. At the bunker the coal from the two beds is picked over separate screens. It is not necessary to pick the coal from the lower bed except to remove pieces of mine timber and fragments which may have broken from the roof and floor. The upper bench is picked more carefully to remove the shale partings which in many places are present in the coal.

Samples for analysis.—Sample 9104 was taken from the McKay bed on the side of the gangway between chutes 73 and 74 of the sixth level. The bed has a fairly good roof and floor and what impurities break from them are separated at the bunker. Sample 9107 was taken from the Upper McKay bed at the place from which sample 9104 was taken. The bed contains several partings of shale and bony coal which can be separated from the good coal by very careful picking and washing, and these were not included in the sample. The analyses of these coals will be found on page 48.

Character and quality of the coal.—The coal of the McKay bed is pitch black, has a dark-brown streak, and breaks with a slightly conchoidal fracture along the lines of minor joints. In other directions the fracture is irregular. It is massive and has a vitreous luster. It contains a small amount of moisture and does not slack on exposure to the sun. A small amount of gas, which is given off from the coal very slowly and which accumulates at the top of the working rooms, makes necessary the use of safety lamps. The coal is noncoking, and compares very favorably with the better grades of bituminous coal obtained in the Eastern States. The coal of the Upper McKay bed is pitch black, and has a dark-brown streak and a somewhat splintery fracture. It may be readily distinguished from coal from the McKay bed by its slightly banded texture. It contains about the same amount of moisture as the McKay, and does not slack when exposed to the sun, but the amount of ash is much greater than in the McKay, owing to the presence of thin layers of carbonaceous shale in the upper layer of the coal. Like the McKay, it is a noncoking bituminous coal of good quality.

SURFACE EXPOSURE AT FRANKLIN.

Surface exposure at Franklin, on opposite side of Green River from the old Sullivan mine of the Pacific Coast Coal Co. No. 15.

Kind of coal: Bituminous.

Coal bed.—This coal bed is known as the McKay. The outcrop from which the sample was taken is the southeasternmost limit of the McKay bed as known at the present time. It strikes north and south and dips about 52° W. The bed is somewhat thinner at this point than to the northwest. The following section was taken where the sample was obtained:

Section of McKay coal bed at Franklin.

No. 9484.

	Ft.	in.
*Coal	4	3½
Shale, carbonaceous		3½
Shale.		
	4	7

Sample for analysis.—Sample 9484 was taken by removing about 2 inches of coal from the surface of the bed and channeling according to the usual method. The bed had been exposed to the air for a considerable length of time, and portions of it were overgrown with moss. The coal is separated from the floor by about 3½ inches of carbonaceous shale, which may break from the floor and mix with the coal in mining. The analysis of this sample is given on page 48.

Character and quality of the coal.—The coal is pitch black and has a dark-brown streak and a vitreous luster. It breaks with a somewhat conchoidal fracture along the lines of the minor joints. Elsewhere the fracture is irregular. It contains a small amount of moisture, and does not crumble when exposed to the sun. The heating value of this sample, though taken from a surface which had been exposed to the weather for a long time, is greater than that of any of the other samples taken from the McKay bed. The coal is noncoking and is classed as a high-grade bituminous coal.

KUMMER.

Kummer, water-level drift on north bank of Green River, about one-fourth mile south of Kummer, on the Columbia & Puget Sound Railroad. No. 16.

Operator: Denny-Renton Clay & Coal Co., Seattle, Wash.

Kind of coal: Subbituminous.

Coal beds.—Several beds of coal and carbonaceous matter are exposed, and the better beds of coal are worked in conjunction with several layers of clay, which are used in the manufacture of brick and terra cotta. The two coal beds from which samples were taken are very close together. They strike nearly north and south and dip about 40° E. The following sections were measured at the places from which the samples were obtained:

Sections of coal beds in Kummer mine.

No. 9113, bed No. 1.	Ft.	In.
Shale, black, carbonaceous.		
*Coal, bright	3	8½
Shale, brown, soft		1
*Coal, bright		5
Shale.		
	4	2½

No. 9115, lower bed.	Ft.	In.
*Coal, slightly bony		9
*Shale, hard, black, carbonaceous		½
*Coal		3½
Shale, black, carbonaceous.		3
*Coal, hard, containing some bony layers	2	9½
Shale, hard, black, carbonaceous.	3	8½
Coal bed	4	1½

Preparation for market.—No attempt is made to separate the impurities from the coal in the mine. The coal is picked at the bunker to remove the shale that breaks from the roof and floor and is mixed with the coal which is used by the company owning the mine for the manufacture of brick and is not cleaned as well as it would be if it were placed upon the open market.

Samples for analysis.—Sample 9113 was taken from the north side of the chute about 1,500 feet north of the entrance to the gangway on bed No. 1, and about 60 feet up the rise from the water level. The bed contains one shale parting, which can be separated by careful picking and washing and was therefore not included in the sample. The roof and floor are of shale, which breaks off to some extent and should be removed from the coal in preparing it for use. This bed is the only one worked at present. Sample 9115 was taken from the lower bed from the side of a cross tunnel about 100 feet south of the entrance to the gangway of bed No. 1. The bed contains thin layers of hard black shale and a large amount of bony coal that can be separated from the good coal only with difficulty. The 3-inch shale parting near the bottom of the bed, however, can be separated by careful picking, and this parting was not included in the sample. The coal is underlain by hard black carbonaceous shale containing stringers of coal. This shale does not part readily from the lower bench of the bed, but will have to be separated from the coal in preparation for the market. The analyses of these samples are given on page 48.

Character and quality of the coal.—The coal of bed No. 1 is pitch black, and has a dark-brown streak and a vitreous luster. It is massive and slightly laminated, and breaks with an irregular fracture. Although it contains a moderate amount of moisture and crumbles when exposed to the direct rays of the sun, it will stand shipment to considerable distances in closed cars. It is a high-grade subbituminous coal and has a heating value somewhat higher than that of any of the other subbituminous coals in the State. Its amount of fixed carbon is considerable higher than that of any other subbituminous coal in the State, and somewhat higher than the McKay coal, which is considered a high-grade bituminous coal. The coal from the other bed is nearly pitch black and has a dark-brown to reddish brown streak. It has a banded, shaly structure and breaks with an irregular fracture. It contains considerable moisture and weathers when exposed to the direct rays of the sun. Owing to its excessive amount of ash, the coal is at present of little commercial value. It was used at one time as fuel for the boiler which operates the bunker and hoisting machinery, but as it was found unsatisfactory its use has been discontinued. It is a high-grade subbituminous coal, but its great amount of ash reduces its heating value to a figure much lower than that of any other high-grade subbituminous coal of the State.

GEM.

Gem, water level and slope mine at Franklin, on the Columbia & Puget Sound Railroad. No. 17.

Operator: Pacific Coast Coal Co., Seattle, Wash.

Kind of coal: Bituminous.

Coal bed.—The coal bed operated at this mine, known as the Gem, lies about 500 feet stratigraphically above the McKay bed at Franklin. It strikes N. 2° W. and dips from 53 to 55° W. The thickness of the bed varies from 2½ to 4 feet in different parts of the mine. The following section was taken at the place from which the sample was obtained:

Section of Gem coal bed in Gem mine.

No. 9103.

	Ft.	in.
Shale, bony.		
* Coal	3	6½
Shale, bony.		

Preparation for market.—The bed is inclined at an angle too high to permit separation of impurities during mining. Bony coal and shale from the hanging and foot walls and "niggerheads," which are frequent in some parts of the mine, are removed by picking at the bunker.

Sample for analysis.—Sample 9103 was taken 10 feet up chute 9 from the entrance to the lower water-level gangway. Both the hanging and foot walls are firm in this part of the mine, but in other parts they are mixed to some extent with the coal and must be separated from it in preparing it for the market. The analysis of this sample is given on page 48.

Character and quality of the coal.—The coal is pitch black and has a dark-brown streak and vitreous luster. It is somewhat banded and laminated and breaks with an irregular fracture. It contains a small amount of moisture and does not weather when exposed to the air. Ash is present in greater amount than in the McKay bed but to about the same extent as in the upper McKay bed. When loaded on cars for shipment, the lumps can not be distinguished from the lumps of the upper McKay. Like the coal from other mines in this immediate vicinity it is noncoking.

SURFACE EXPOSURE SOUTHWEST OF FRANKLIN.

Surface exposure on south bank of Green River, about three-fourths of a mile southwest of Franklin. No. 18.

Kind of coal: Bituminous (?).

Coal bed.—The coal bed is exposed in an open cut about 20 feet above the bed of the river. A drift has been driven on the strike for a distance of about 70 feet in the lower part of the bed. The coal at the end of the drift was covered with mud and water which had seeped through from above. The coal at the surface when dressed for sampling appeared much more free from impurities than the coal in the drift, and the sample was therefore taken at the surface. The bed is believed to be the same as the Gem which is worked at Franklin. It strikes N. 22° W. and dips 60° SW. The following section was taken where the sample was obtained:

Section of Gem (?) coal bed in surface exposure three-fourths of a mile southwest of Franklin.

No. 9487.

	Ft.	In.
Coal, minutely jointed		5
Coal, cubic fracture		8½
Coal, bony		1
Bone with thin stringers of coal		5
Shale with thin layers of bone and coal		8½
Shale, black, with layers and stringers of coal	1	2½
Coal, bony	1	2½
*Coal	2	8½
Shale, black, carbonaceous.		
	7	5½

Sample for analysis.—Sample 9487 was taken from this bed. The layer sampled is overlain by bony coal and underlain by carbonaceous shale, both of which would probably adhere to some extent to the coal and should be separated from it in preparation for the market. The analysis is given on page 48.

Character and quality of the coal.—The coal is nearly pitch black and has a dark-brown streak. It is slightly banded and laminated and has an irregular fracture. The sample as received at the laboratory has a somewhat high percentage of moisture, but whether the coal will slack on exposure to the sun is not known. The surface of the exposure was kept moist continually by a spray from a small stream which falls down along the footwall of the bed, so that the coal was not exposed to the action of the air. The coal is noncoking and should be classed as either a very high-grade subbituminous or a low-grade bituminous. Its heating value is about the same as that of the better grades of subbituminous coal obtained in the State.

ROSE-MARSHALL.

Rose-Marshall, slope mine, about 1 mile west of Cumberland, Wash., on a proposed extension of the Northern Pacific Railway. No. 19.

Operator: Rose-Marshall Coal Co., Seattle, Wash.

Kind of coal: Bituminous.

Coal bed.—The coal bed is known as the John Harris bed and is supposed to be one of a group mined at Franklin and Black Diamond.

The beds strike nearly north and south and dip about 60° W. The following section was measured where the sample was cut:

Section of John Harris coal bed in Rose-Marshall mine.

No. 10512.

	Ft.	In.
Shale, roof.		
Coal, with layers of bone and clay	5	
*Coal	1	1
Shale, carbonaceous		2
*Coal, cubical fracture	5	
Coal, bony.		
	11	3

Preparation for market.—No bunkers for cleaning and storing the coal had been erected at the time of the writer's visit.

Samples for analysis.—Sample 9293 was taken by cutting channels across the face of six lumps of coal stacked under a small cover near the entrance to the slope. The mine was filled with water above the point in the slope where the bed was first encountered. These lumps which were sampled had been exposed to the direct rays of the sun for at least a part of the day for about three months, but the coal was bright and fresh and showed no indications of weathering. Sample 10512 was obtained by G. W. Evans in April, 1910, after the mine had been reopened and placed in operation. It was taken 500 feet down the slope from the surface and on the left-hand side. A layer of carbonaceous shale in the bed, which can be separated from the coal by picking and washing, was not included in the sample. The coal was moist when taken from the mine and sealed in the can, and the analysis shows a slightly higher percentage of moisture than an analysis of a dry sample. The analyses of these samples are given on page 49.

Character and quality of the coal.—The coal is pitch black in color and has a dark-brown streak. It is banded and has either a slightly irregular conchoidal fracture or a somewhat cubical fracture. It contains a small amount of moisture and does not weather when exposed to the sun. In heating value it compares favorably with many of the bituminous coals of the east and with the McKay coal at Black Diamond and Franklin.

INDEPENDENT.

Independent, slope mine, about 1 mile south of Cumberland, Wash., No. 20.

Operator: Independent Coal Co.

Kind of coal: Bituminous.

Coal bed.—One coal bed, which strikes N. 30° E. and dips 55° SE., is exposed. The section given below was taken at the foot of the slope, which has been sunk to a depth of only about 20 feet.

Section of coal bed in Independent mine.

	Ft.	In.
Shale, black, carbonaceous.		
*Coal, bony (sample No. 9474)	3	5
*Coal (sample No. 9286)	2	2½
*Coal, bony (sample No. 9286)	1	2½+
Covered	1	2½
Shale, carbonaceous, black.		
	8	½+

Samples for analysis.—Samples 9474 and 9286 were taken from the two benches of the bed at the foot of the slope. Sample 9474 was taken from the upper bench and sample 9286 from the lower bench of the bed. About 14 inches of the lower part of the lower bench was covered and could not be sampled, so that the character of this part of the bed is not known. Both hanging and foot walls are firm, and will probably not mix appreciably with the coal. The analyses of the samples are given on page 49.

Character and quality of the coal.—The coal from the upper bench is grayish black and has a brown streak. It is banded and breaks with a conchoidal fracture. The amount of moisture present in it is relatively small and the coal does not weather when exposed to the air. The amount of ash is very high, but the heating value is sufficient to make the coal marketable. It is a noncoking bituminous coal and resembles the coal from bed No. 5 at Ravensdale. The coal from the lower part of the lower bench resembles that from the upper bench but is higher in ash. The coal from the upper part of the lower bench is pitch black; has a dark-brown streak and a vitreous luster. It is only slightly banded, and breaks with an irregular splintery fracture. It appears to be much lower in ash and to have a much higher heating value than any of the other layers in the bed. The coal appears to be of high grade, and resembles that from bed No. 5 at the Green River Coal Co.'s mine. This portion of the bench, if worked with the upper bench, would give a product with only a moderate amount of ash.

SUNSET.

Sunset, water-level mine, about 1 mile southeast of Cumberland. Bunkers are located on the Northern Pacific Railway about 1 mile from the mine. No. 21.

Operator: Sunset Coal Co., Cumberland, Wash.

Kind of coal: Bituminous.

Coal beds.—Three coal beds have been worked. Bed No. 1, the highest in the group, was worked by a water-level gangway, which has been abandoned and closed up. Beds No. 2 and No. 3 are benches of a lower bed of coal, and are worked together in some parts of the mine. Bed No. 7 outcrops farther to the north on the hill and several hundred feet lower down in the formation. The beds strike about N. 60° E. and dip from 42° to 60° SE. The thickness of beds No. 2 and No. 3 varies considerably within short distances, and the partings are somewhat irregular. No. 2 and No. 3 are the only beds worked at the present time. The following sections were measured at the places from which the samples were taken:

Sections of coal beds in Sunset mine.

No. 9263, bed No. 1.

	Ft.	In.
Shale.		
Coal, bony		7
*Coal	4	8½
Coal, bony.		
	5	3½

No. 9265, bed No. 3.

	Ft.	In.
Shale, soft.		
*Coal	1	3½
Sand, brown		1
*Coal	1	
Shale, carbonaceous		1½
Clay		3
Sandstone, carbonaceous		3½
Coal		4
Coal, bony		4
	3	8½

No. 9264, bed No. 2.

	Ft.	In.
Shale, carbonaceous.		
*Coal	1	6½
Shale		1
*Coal		8½
Shale, carbonaceous, soft, black		2½
*Coal, bony		9½
	3	4

No. 9276, bed No. 7.

	Ft.	In.
Bone (roof).		
*Coal, bony	2	
Shale, black, carbonaceous.		2½
*Coal		6
*Coal, bony		11
*Coal, bony	2	5
Bone, with some coal (floor)	1	
	7	½

Preparation for market.—No attempt is made to separate the impurities at the mine. The partings are separated from the coal by picking and washing at the bunkers.

Samples for analysis.—Sample 9263 was taken from the side of an air chute on bed No. 1, about 30 feet down the dip from the surface. The air chute comes to the surface about 20 feet below the crest of the first ridge east of the entrance to the mine, and this was the only place where a sample from this bed could be obtained. The coal had been exposed to the atmosphere for a considerable length of time and was somewhat weathered. The bed lies between two layers of bony coal, which cling more or less to the coal and should be picked out at the bunkers. Sample 9264 was taken from bed No. 2 about 1,450 feet from the entrance to the mine. This bed contains two partings, which can be separated by picking and washing and were not included in the sample. Sample 9265 was taken at the same place as No. 9462, but from bed No. 3. It contains a parting of sand, which can be removed by washing and was not included in the sample. Between this bed and bed No. 2 is a layer of soft shale, of which a part can be removed in the mine and the rest separated at the bunkers. The bed is underlain by about 16 inches of shale and more or less impure coal which may be mixed to some extent with the coal in mining, but it can probably be removed by careful picking and washing. Sample 9276 was taken from bed No. 7 about 30 feet from the entrance to the drift which is located on the hill about 300 feet due north from the bunk house. The bed contains some bony coal and one layer of black shale; the black shale can be separated and was not included in the sample. The roof and floor are both of bone and should not mix much with the coal. The analyses of these samples are given on page 49.

Character and quality of the coal.—The coal from beds Nos. 1, 2, and 3 is pitch black and has a dark-brown streak. The luster of most of the coal is vitreous, but some from bed No. 1 displays very beautiful peacock colors. The coal is banded and laminated and breaks with an irregular, splintery fracture. Considerable moisture was found in the sample taken from bed No. 1, but this moisture may be due to absorption during weathering. The coal from beds No. 2 and No. 3 contains a small amount of moisture and does not slack on exposure to the air, but that from No. 2 bed is rather high in ash, owing probably to the presence of a bony layer near the bottom of the bed. All three beds are bituminous, and the coal compares favorably with that taken from beds Nos. 1 and 3 at Bayne. Coal from beds No. 2 and No. 3 shows fair coking tendencies and is sometimes used in blacksmithing. The coal from bed No. 7 is grayish black and has a reddish-brown streak. It is banded and laminated and breaks with a splintery fracture. Inasmuch as its heating value is greatly reduced by the excessive amount of ash contained in it, this coal may be of little economic value until the better coals are exhausted.

NAVAL.

Naval, water-level and slope mine at Cumberland, on the Northern Pacific Railway. No. 22.

Operator: Naval Coal Co., Cumberland, Wash.

Kind of coal: Bituminous.

Coal bed.—Two beds of coal, No. 4 and No. 6, are worked at this mine. They are separated by about 12 feet of carbonaceous shale, which is left standing after the two beds are worked out. The following section was measured in the places where the samples were taken:

Section of coal beds in Naval mine.

	Ft.	in.
Clay shale.		
Shale, white		3½
Bone		3½
*Coal (sample 9287)		11
Shale		½
*Coal (sample 9287)	1	6
Shale, carbonaceous	10	
Coal, hard, bony	2	
*Coal, fat, bony (sample 9285)	1	7
*Coal (sample 9284)	2	4
	18	11½

Preparation for market.—No attempt is made to separate any of the impurities in the mine. The coal is picked at the tipple over 2-inch bar screens.

Samples for analysis.—Sample 9287 was taken from bed No. 4 at the first crosscut above the water-level gangway in a chute 144 feet north of the rock tunnel. The bed contains one shale parting, which can be separated from the coal and was not included in the sample. Layers of shale and bone, in all about 7 inches in thickness, overlay the bed and mix to some extent with the coal. These impurities must be removed at the tipple. The shale floor is firm and does not mix with the coal. Sample 9285 was taken from the north water-level gangway, about 330 feet from the rock tunnel, from the upper bench of bed No. 6. Sample 9284 was taken from the same place as sample 9285, but from the lower bench of the bed. The bed is between two layers of bony coal, which appear to be firm and should not mix to any extent with the coal. The analyses of these samples are given on pages 49–50.

Character and quality of the coal.—The coal from bed No. 4 and the upper bench of bed No. 6 is grayish black and has a reddish-brown streak. It is banded and laminated, and breaks with a splintery fracture. It contains a small amount of moisture and does not weather when exposed to the air. The amount of ash in both beds is somewhat high, but the heating value is sufficient to make the coal of commercial value. The coal of the lower bench of bed No. 6 is pitch black and has a dark-brown streak and a vitreous luster. It is slightly banded and has an irregular splintery fracture. It contains a small amount of moisture and does not weather when exposed to the atmosphere. In ash content, which is moderate, the coal compares favorably with the best coal in bed No. 5 at Bayne and the coal from bed No. 3 at Occidental. The coal from bed No. 4 and from the upper bench of bed No. 6 shows a tendency to coke and that from the lower part of bed No. 6 should produce fairly good coke. This coal should be classed as a fair grade of bituminous coal.

EUREKA.

Eureka, abandoned water-level mine about 1 mile south of Bayne. No. 23.

Kind of coal: Bituminous.

Coal bed.—The coal bed belongs to the same group of beds as that exposed in the mine of the Green River Coal Co. at Bayne. It strikes N. 85° W. and dips 38° SW. The bed, as exposed in the gangway, contains a great number of partings of shale and bony coal, and only a portion of it is pure enough to be mined economically at the present time. The section following was measured.

Section of coal bed in Eureka abandoned mine.

No. 9294.

	Ft.	in.
Shale, black, carbonaceous	1	1
*Coal	1	
Shale, brown		2½
*Coal	2	1
*Coal, crushed, and carbonaceous shale?	1	
"Sulphur" band and sandy shale		2½
*Coal		9½
Bone and shale		5
Coal		3½
Shale		2½
Coal		5
Shale		1
Coal		3½
Bone and shale		2½
Mixture bone and shale crushed	1	7
Bone		3½
Coal, crushed, bony		6
Shale, carbonaceous		2½+
	10	10½

Sample for analysis.—Sample 9294 was taken from the side of the gangway 174 feet from the entrance to the mine. Two partings which occur in the bed can be separated by careful picking and washing, and were not included in the sample. The analysis of the sample is given on page 50.

Character and quality of the coal.—The coal is pitch black and has a dark-brown streak and a vitreous luster. It is banded and breaks with an irregular fracture. It contains a small amount of moisture and does not weather when exposed to the air. Although the amount of ash in the sample is large, the heating value is high enough to make the coal of considerable commercial value. The coal is bituminous and of about the same quality as that from beds No. 1 and No. 2 at Bayne.

BAYNE.

Bayne, water-level tunnel and drift mine at Bayne, on the Northern Pacific Railway. No. 24.

Operator: Green River Coal Co., Seattle, Wash.

Kind of coal: Bituminous.

Coal beds.—Three coal beds, Nos. 1, 3, and 5 in ascending order, are being worked in this mine. One is separated from another by several hundred feet of sandstone. The beds strike N. 30° W. and dip 34° NE. They are uniform in thickness and the partings are fairly continuous. The following sections were measured where the samples were obtained:

Sections of coal beds in Bayne mine.

No. 9112, bed No. 1.

	Ft.	in.
Shale, black.		
*Coal		10
*Shale, black, carbonaceous, hard		½
*Coal	1	9½
Shale, soft, carbonaceous		3½
*Coal		3½
Shale, hard		1
*Coal, with small "niggerheads"	1	1
Shale, black, carbonaceous		2
*Coal		3½
Shale, carbonaceous		½
*Coal		3½
Shale, black		2
*Coal	1	2½
Shale, brown, carbonaceous.		
	6	7

No. 9109, bed No. 5.

	Ft.	in.
Shale.		
Shale, black		7
*Coal	2	2½
Shale, soft, brown, carbonaceous		2½
*Coal	2	7
Shale, carbonaceous.		
	5	7

No. 9110, bed No. 3.

	Ft.	in.
Shale, sandy.		
*Coal	1	8½
Shale, carbonaceous, very soft		2½
*Coal		9½
Shale, gray		1
*Coal		4
Shale, gray		2
*Coal		5
Shale, gray		2½
*Coal		1
Shale, gray		1
*Coal		7
Shale, black, carbonaceous.		
	4	8

Nos. 9268, 9269, 9275, bed No. 5.

	Ft.	in.
Shale, soft, carbonaceous.		
*Coal	2	
Shale, carbonaceous.		

No. 9483, highest bed on hill.

	Ft.	in.
Shale.		
*Coal		2
Shale, carbonaceous		1
*Coal, slightly bony	1	
Sand		½
*Coal, stringy and slightly bony		8
Clay, yellowish.		
	1	11½

Preparation for market.—No attempt is made to separate the partings from the coal in the mine. At the bunker the coal is passed over a shaking screen having 2-inch perforations; the oversize is hand picked and the undersize washed twice through a new model of the Pittsburg jig, which is supposed to remove 95 per cent of the impurities.

Samples for analysis.—Sample 9112 was taken on the north side of the main rock tunnel where it crosses bed No. 1. The bed contains numerous partings, most of which have a higher specific gravity than the coal and can be separated by carefully adjusting the washers. The top parting only was included in the sample. Sample 9110 was taken from the face of the south gangway on bed No. 3, about 70 feet from the main tunnel. This bed also contains numerous shale partings, which can be separated from the coal by very careful picking and washing, which were not included in the sample. Sample 9109 was taken on bed No. 5, 55 feet above the gangway and 15 feet to the left of chute 9. The bed contains one shale parting that can be separated from the coal, and was not included in the sample. Both the roof and the floor of the mine are very firm and do not mix with the coal in mining. Samples 9275, 9268, and 9269 were taken from the lower 2 feet of good coal from bed No. 5 in a small drift at the outcrop of the bed on the hill above the entrance to the mine, to show the effect of weathering upon this grade of coal. Sample 9275 was taken at the entrance to the drift 1 foot beyond the first set of timbers. The coal was weathered and much jointed, the joints being filled with mud and iron rust. Sample 9268 was taken 9 feet beyond the first set of timbers. The coal, which appears to be somewhat shaly at this point, was weathered, and the major joints were filled with mud and iron rust. Sample 9269 was taken 15 feet from the first set of timbers. The coal was bright and firm and represents about the best coal that could be obtained from bed No. 5 in the mine proper. Sample 9483 was taken from the highest bed on the hill above the Bayne mine. It was very poorly exposed in a small prospect, and appeared to be faulted out of its regular position in the group. It contains several partings which can be separated by careful picking and washing, and these partings were not included in the sample. The analyses of these samples are given on pages 50–51.

Character and quality of the coal.—The coal from beds Nos. 1, 3, and 5 is nearly pitch black and has a dark-brown streak and a vitreous luster. It is massive and laminated and breaks with an irregular fracture. It contains a small amount of moisture and does not crumble when exposed to the air. All the samples, except the one taken from the lower bench of bed No. 5, show a high percentage of ash. A small amount of gas is liberated after the coal is shot, and this accumulates in sufficient quantities to necessitate the use of safety lamps until the rooms can be tested and brushed out. This coal is bituminous and of good grade; the large amount of ash accounts for the low heating value. The coal shows coking tendencies, and is used at the mine as blacksmithing coal for rough work. Coal from the small prospect at the top of the hill contains little moisture, but the high percentage of ash makes it of little economic value at the present time.

Comparison of the analyses of the three samples from the drift on bed No. 5 shows a decrease in moisture and sulphur and an increase in volatile matter in the coal as the distance from the entrance increases. The increased amount of ash in the second sample is probably due to the greater thickness of the films of mud in the joints and to the more bony nature of the coal.

CARBON.

Carbon, a water-level mine about half a mile northeast of Bayne, on the Northern Pacific Railway. No. 25.

Operator: Carbon Coal Co., Bayne, Wash.

Kind of coal: Bituminous.

Coal bed.—The bed worked at this mine is believed to belong to the same group as that mined by the Green River Coal Co. at Bayne. It strikes N. 45° E. and dips about 10° SE. The upper bed, or bed No. 1, is the only one that is being worked. Bed No. 2 is separated from No. 1 by a parting that increases in thickness from a few feet at the far end of the gangway to about 25 feet at the entrance of the mine. The following sections were measured where the samples were taken:

Sections of coal beds in Carbon mine.

No. 9485, bed No. 1.	Ft.	In.	No. 9489, bed No. 2.	Ft.	In.
Shale, clayey.			Shale, brown, sandy.		
Coal, bony		1	*Coal	2	8½
*Coal	2	9½	Shale.		
Shale, sandy		2½			
*Coal		9½			
Shale, clayey		1			
*Coal		5 +			
Shale.					
	4	4½+			

Preparation for market.—The coal contains numerous "nigger-heads" varying in maximum diameter from 2 inches to several feet, most of which are separated from the coal in the mine. The coal is picked at the bunker and washed through a jig.

Sample for analysis.—Sample 9485 was taken from bed No. 1 at a point 630 feet west and 590 feet north of the southeast corner of sec. 15, T. 21 N., R. 7 E. The bed contains two partings, which, since they can be separated by careful picking and washing, were not included in the sample. About an inch of bony coal overlies the bed and is mixed with the coal to some extent in mining. It is necessary to remove this at the bunker. Sample 9486 was taken from spherical nodules of coal, which occur frequently throughout the bed and range from 2 inches to a foot in diameter. Coal of this character appears to be brighter and more nearly pure than the remainder of the bed. Analysis 9492 was made of a composite sample consisting of equal parts of the coals tested in samples 9485 and 9486. Sample 9489 was taken from bed No. 2 at a point 380 feet west and 844 feet north of the southeast corner of the same section. At this place the bed is separated from bed No. 1 by about 2 feet of coal, clay, and shale. The coal is worked only in the gangway, where the floor is taken up to give sufficient height for handling cars. The analyses of these samples are given on page 51.

Character and quality of the coal.—The coal from both beds is pitch black, and has a dark-brown streak and a vitreous luster. It is massive and slightly laminated, and breaks with an irregular hackly fracture. In general, the coal from these beds contains a small amount of moisture and does not weather on exposure to the sun, and that obtained from the spherical nodules contains a smaller percentage of moisture and ash and a greater percentage of volatile matter and fixed carbon than the remaining coal of the bed. The coal forms fair coke and is a bituminous coal of about the same quality as that obtained from the best beds in the vicinity of this mine.

PROSPECT DRIFT WEST OF BAYNE.

Prospect drift about one-fourth mile west of Bayne and about 600 feet west and 140 feet south of the northeast corner of sec. 21, T. 21 N., R. 7 E. No. 26.

Kind of coal: Bituminous.

Coal bed.—This coal bed belongs to the same group as that exposed at Occidental and at Bayne. It is very nearly horizontal, and lies in the center of the syncline passing through Lizard Mountain. At the point in the drift where the sample was taken the bed strikes about N. 60° E. and dips nearly 8° NW. The partings in the bed are not uniform in thickness throughout the length of the bed exposed in the drift. The following section was measured where the sample was taken:

Section of coal bed in prospect drift west of Bayne.

No. 9488.

	Ft.	In.
Shale, carbonaceous.		
*Coal		8½
Shale, black, carbonaceous		½
*Coal	1	6
Shale, brown, sandy		2½
*Coal		8½
Shale, sandy		1
*Coal		11
Shale, sandy, carbonaceous		1
*Coal	1	3½
Shale.		
	5	6½

Sample for analysis.—Sample 9488 was taken 72 feet from entrance on the upper side of the gangway. The bed contains four partings, which can be separated by careful picking and washing and which were not included in the sample. The analysis of this sample is given on page 51.

Character and quality of the coal.—The coal is pitch black, and has a brown streak and a vitreous luster. It is massive and slightly laminated and breaks with an irregular hackly fracture. It contains a small amount of moisture and does not weather on exposure to the air. The analysis shows a rather high amount of ash, but the heating value is high enough to make the coal of commercial value, and it should compare favorably with the coal from other mines in the immediate neighborhood. Coking tendencies are apparent in coal taken from this prospect.

OCCIDENTAL.

Occidental, two slope mines and one drift, at Bayne, on a spur of the Northern Pacific Railway. No. 27.

Operator: Occidental Colliery Co., Seattle, Wash.

Kind of coal: Bituminous.

Coal beds.—Sixteen beds of coal and carbonaceous material, numbered in descending order, are reported in this group. Beds Nos. 1, 2, 3, 4, 5, 6, and 14 have been developed at different times. At the time of the visit to the mine the openings on Nos. 4 and 5 were closed, and these beds could not be sampled. The beds strike N. 45° E. and dip about 38° SE.; both beds and partings are about uniform in thickness throughout the workings. The following sections were measured at the places where the samples were obtained:

Sections of coal beds in Occidental mine.

No. 9479, bed No. 1.

	Ft.	In.
Shale.		
Clay and coal, irregular streaks	1	
*Coal	1	5
Shale, slightly bony, altered locally to "niggerheads"		3½
*Coal, bony		1
*Coal, bright	4	1
Coal, bony.		
	6	10½

No. 9478, bed No. 3.

	Ft.	In.
Shale, carbonaceous.		
*Coal, slightly bony near center	1	5
Clay		1
*Coal, hard, bright	1	11
Shale		2½
*Coal	1	5
Shale, black		8½
	5	9

No. 9481, bed No. 6.

	Ft.	In.
Shale, black, carbonaceous.		
*Coal	1	2½
"Sulphur" band		1
*Coal	1	5
Shale, brown, sandy		3½
*Coal		7
Shale, brown, soft.		
Shale, smooth.		
	3	7

No. 9476, bed No. 14.

	Ft.	In.
Coal, bony.		
*Coal, hard, bright	1	6
Shale.		

No. 9480, bed No. 2.

	Ft.	In.
Shale, black, carbonaceous.		
*Coal, bright	1	1
Shale, sandy, brown, varies up to 3½ inches		1
*Coal		2
Clay, soft, pale yellow, varies from 1 to 5 inches		2½
*Coal		3
Shale, brown, carbonaceous		½
*Coal, bright	1	5
Shale, brown		½
*Coal, bright		5½
	3	9

No. 9475, bed No. 3.

	Ft.	In.
Shale, black.		
*Coal		11½
Bone		½
*Coal		8½
Bone		½
*Coal	1	9½
Shale		2½
*Coal		11
Shale, sandy		½
*Coal		5
Shale, floor.		
	5	1½

No. 9477, bed No. 14.

	Ft.	In.
Shale, carbonaceous.		
*Coal, hard, bony	1	
*Coal, soft, bony		½
*Coal	2	9½
*Coal, hard, bright	1	6
Shale		1
*Coal		8½
Shale, carbonaceous.		
	6	1½

Preparation for market.—Coal from the beds No. 2 and No. 3 is picked, and then washed through a small jig at a dump house near the entrance to mine No. 3. Numerous "niggerheads" occur in bed No. 2; the largest of these are separated from the coal in the mine, and the others are removed at the bunker. Coal from bed No. 14 is hand picked at another dump house at the entrance to the slope of bed No. 14, or what is known as the new mine.

Samples for analysis.—Sample 9479 was taken from the abandoned workings on bed No. 1 on the side of an air course 550 feet from the entrance to the first water level and on the counter gangway 250 feet above the water level gangway. The bed contains a layer of bony shale, altered locally to "niggerheads," which may be separated from the rest of the coal and was not included in the sample. The coal is overlain by about a foot of irregular bands of clay and coal, which will come down to some extent in the rooms and must be removed at the bunker. Sample 9480 was taken on bed No. 2, about 70 feet up a chute 310 feet from entrance to the gangway. The bed contains several partings, which can be separated by careful picking and washing and which were not included in the sample. The roof is of carbonaceous shale, and is not mixed to any extent with the coal in mining. Sample 9478 was taken from bed No. 3 about 100 feet above the first level on the manway 30 feet northeast of the slope. The bed contains two partings which can be removed by picking and washing and which were not included in the sample. Sample 9475 was taken from the same bed about 660 feet up the rise from the first level in chute 7. The bed contains four partings, which can be separated in preparation for market and were therefore not included in the sample. Both roof and floor are firm and do not mix with the coal in mining. Sample 9481 was taken from the south side of an old air course on bed No. 6, about 112 feet from the surface. The air course is located about 300 feet northeast from chute 7 on bed No. 3. Two partings which occur in the bed can be separated from the coal in preparation for the market, and were not included in the sample. The roof of the mine is firm and is not mixed with the coal in mining, but the bed is underlain by 2½ inches of soft shale which parts from the floor with the coal and must be removed at the bunker. Sample 9477 was taken from bed No. 14 at the New mine about 200 feet down the slope and 30 feet to the west, where a small room had been opened to supply the boiler with fuel. A parting near the bottom of the bed can be separated and was not included in the sample. The roof and floor are firm and are not mixed to any extent with the coal. Farther west and southwest along the gangway the bed is badly crushed, and the roof and floor become mixed to a considerable extent with the coal, introducing impurities which must be removed at the bunker. Sample 9476 was taken from the same place as sample 9477, and is composed of coal from the 1 foot 6 inch bench of good coal in the lower portion of the bed. Analysis 9491 was made of a composite sample containing equal parts of samples 9476 and 9477. The analyses of these samples are given on pages 51–52.

Character and quality of the coal.—The coal from beds Nos. 1, 2, and 3 and the lower part of bed No. 14 is pitch black and has a dark-brown streak and a vitreous luster. It is massive and very slightly laminated and breaks with an irregular fracture. It contains a small amount of moisture and does not crumble when exposed to the sun. This coal, except that from the lower bench of No. 14, contains about the same amount of ash as most of the coal in the vicinity of Bayne. Gas occurs in the coal in such quantities as to make necessary the use of safety lamps after shooting, or after the workings have stood vacant for some time. The coal is bituminous, and is used to some extent as blacksmith coal, as it will coke in the forge. It has about the same heating value as the better grades of coal from the immediate vicinity. The coal from bed No. 6 and from the upper bench of bed No. 14 is grayish black, and has a dark-brown streak and a dull luster. It is banded and laminated, and breaks with a splintery fracture. It contains a small amount of moisture and does not weather when exposed to the sun. More ash is present in it than in the other samples obtained at this mine, and its heating value is correspondingly lower. This coal is bituminous, shows good coking tendencies, and is of about the same value as that obtained from the beds of mine No. 1 at Ravensdale.

BIG SIX.

Big Six, a drift mine about 1½ miles east of Bayne, on a spur of the Northern Pacific Railway. No. 28.

Operator: Bix Six Coal Co., Seattle, Wash.

Kind of coal: Bituminous.

Coal bed.—This mine, which has been closed for some time, is located on what has frequently been called the Pocahontas bed. The bed strikes N. 12° W. and dips about 31° E. The main rock tunnel to the bed is badly caved and was not considered safe at the time of the visit. The main bench of the bed could not be sampled, but a sample of the upper bench was obtained from a small drift made near the fan house on the outcrop of the bed, where the following section was taken:

Section of the Pocahontas bed in Big Six mine.

No. 9278.

	Ft.	In.
Shale, hard, carbonaceous.		
*Coal	1	5
Shale, brown		2
*Coal	1	1
Shale, brown		1
*Coal		4
Shale, carbonaceous, sandy		1
Shale, sandy.		
	3	2

Sample for analysis.—Sample 9278 was taken about 30 feet from the entrance to the drift. The bed contains two partings of shale, which can be separated from the coal by careful picking and washing and were therefore not included in the sample. A foot or two of shale separates it from the main or lower bench of the bed. The analysis of this sample is given on page 52.

Character and quality of the coal.—The coal is pitch black, gives a dark-brown streak, and has a vitreous luster. It is massive and dense and breaks with an irregular fracture. It is low in moisture and does not crumble when exposed to the sun. The ash content is about the same as that of the average coal in the same region. The coal is bituminous, of fair grade, and is reported to make good coke. It has about the same heating value as the better grades of coal from the same region.

PROSPECT AT PALMER JUNCTION.

Prospect at Palmer Junction, on the Northern Pacific Railway. No. 29.

Kind of coal: Bituminous.

Coal bed.—The coal bed appears to belong to the group exposed at Durham on the north and at the Big Six mine on the south. It strikes S. 2° W. and dips 38° E. The total thickness of the bed between hanging and foot walls is 30 feet 3¾ inches. A drift has been driven on the strike in the upper part of the bed to a distance of about 160 feet. A section of the bed follows.

Section of coal bed in prospect at Palmer Junction.

	Ft.	in.
Shale, sandy (hanging wall).		
Shale, black, carbonaceous		2½
Coal, bony		6
Shale, brown		2½
Shale, carbonaceous, with stringers of coal		7
Coal, bony		6
Shale, gray		7
Shale, carbonaceous, with stringers of coal		5
*Coal, bony (sample 9288)	1	3½
Shale, hard, gray		1
*Coal, bony (sample 9288)		8½
Shale, gray		1
Bone		2
Shale, gray		1
Coal, bony		3½
Shale, brown		½
Coal, bony		5
Shale, brown, carbonaceous		3
Shale, carbonaceous, with stringers of bony coal and bright coal	1	
*Coal, bony, with stringers and lenses of good coal (sample 9482)	1	4

	Ft.	In.
Shale, brown, carbonaceous		3½
Coal		1
Shale, brown		5
Sandstone, coarse		3½
Shale, carbonaceous, with lenses of coal	1	
Shale, brown		3½
Coal		2½
Shale, sandy		1
Coal		1
Sandstone, soft		7
Coal, poor		5
Coal		2½
Coal, poor		3½
Shale, sandy		3½
Shale, sandy		3½
Coal, crushed		8½
Coal		7
Shale, brown, with irregular lenses of coal		8½
Coal		2½
"Niggerhead"		5
Coal		3½
Shale, carbonaceous, with stringers of coal		11
Coal, bony	1	
Shale, sandy		1
Coal, bony		3½
Shale, soft, brown		6
Coal		3½
Coal, bony		6
Coal, very poor, bony (coal in thin lenses)	1	9½
Sandstone		3½
Shale, sandy black		3½
Shale, black, carbonaceous		1
Coal		1
Coal, bony		5
Coal		3½
Shale, carbonaceous, with stringers of coal		8½
Coal, poor		1
Shale, hard, sandy		3½
Shale, soft		1
Coal, lens about 2 feet long		1
Shale, carbonaceous, with lenses of coal		9½
Coal, very badly crushed		6
Shale, black, hard, carbonaceous		3½
Coal		5
Shale, carbonaceous, with irregular lenses of coal	4±	
Shale (footwall).		
	30	7

Samples for analysis.—Samples 9288 and 9482 were taken from the surface of the bed just above the entrance to the drift, after about 6 inches of the coal had been removed. Sample 9288 was taken from the upper bench, which contains a small parting not included in the sample. Sample 9482 was taken from the lower bench. The analyses of these samples are given on pages 52–53.

Character and quality of the coal.—The coal from these two benches is pitch black, and has a dark-brown streak and vitreous luster. It is banded and laminated, and breaks with an irregular splintery fracture. It contains a small amount of moisture and does not weather when exposed to the sun. The amount of ash is very large, forming about one-third of the total weight of the coal, and the heating value of the coal is so greatly reduced in consequence that it is only about the same as that of the lowest grade of coal in the State.

PROSPECT SHAFT EAST OF RAVENSDALE.

Small prospect shaft about 3½ miles east of Ravensdale. No. 30.
Kind of coal: Bituminous.

Coal bed.—About 5 feet of the coal bed is exposed in the bottom of the shaft. The bed has been disturbed by local movements so that the sections on both sides of the opening do not agree, and the dip and strike are somewhat uncertain; as near as could be determined from the present opening the bed strikes about N. 80° W. and dips from 80 to 85° S. The following section was taken on the west side of the opening:

Section in Prospect shaft 3½ miles east of Ravensdale.

No. 9292.

	Ft.	In.
Shale.		
*Coal	1	9½
Shale, and carbonaceous shale		2
*Coal		9½
Clay, lens		¼
*Coal		5
Shale, carbonaceous		2½
*Coal	1	5
*Coal, bony		7
Shale.		
	5	4¾

Samples for analysis.—Sample 9292 was taken at the place where the section given above was measured. The bed contains three partings which can be separated from the coal, and these were not included in the sample. It is overlain by crushed shale, which will mix with the coal in mining. The analysis of this sample is given on page 53.

Character and quality of the coal.—The coal is pitch black, and has a dark-brown streak and a vitreous luster. It is slightly banded and has an irregular conchoidal fracture, resembling that of the McKay coal, and this circumstance, among others, has led to the belief that this may be the McKay bed. The coal contains a rather large amount of moisture and a moderate amount of ash, so that its fuel value is considerably lower than the McKay. It has about the same heating value as the average coal from the Ravensdale No. 1 mine, and may be a continuation of one of these beds.

PROSPECT DRIFT NEAR BARNESTON.

Prospect drift run 70 feet, near Barneston, on the Northern Pacific Railway. No. 31.

Kind of coal: Natural coke(?).

Coal bed.—The bed upon which this drift is run is one of a group of coal beds exposed in a small ravine west of the north end of the horseshoe loop on the railroad. All the beds are more or less affected by igneous intrusions, and in some places they are almost completely burned out. The following section was taken about 10 feet from the entrance to the drift.

Section of coal bed in prospect drift near Barneston.

No. 9111.

	Ft.	In.
Igneous rock.		
* Shale, black, with thin streaks of coal	1	2½
Igneous rock		6
* Shale, with streaks of coked coal	3	
	4	8½

Sample for analysis.—Sample 9111 was taken where the above section was measured. Both the hanging wall and footwall of the bed are of a porphyritic igneous rock which appears to be rhyolite or andesite. The parting in the middle of the bed appears to be of the same material, but it is much decayed and can be readily broken in the hand. This parting follows about the same position in the bed for a distance of 30 feet from the entrance. It then turns abruptly and lies immediately under the roof. The analysis of this sample is given on page 53.

Character and quality of the coal.—The coal has been altered by igneous action. The upper bench of the bed is changed almost entirely to natural coke, and the lower bench is partially altered. The analysis indicates a large amount of fixed carbon and a small amount of volatile matter. The coal contains a high percentage of moisture, nearly all of which is given off when exposed to the sun. This moisture appears to fill the pore spaces in the coked part of the bed, and has probably been absorbed from the adjoining rocks. Nearly one-third of the weight of the coal is ash. It has a low heating value, and considering the uncertain nature of the igneous intrusions in this vicinity the bed is of no economic importance.

DENNY-RENTON.

Denny-Renton, tunnel and drift mine at Taylor, on the Columbia & Puget Sound Railroad. No. 32.

Operator: Denny-Renton Clay & Coal Co., Seattle, Wash.

Kind of coal: Bituminous.

Coal bed.—Five coal beds are exposed in this tunnel, which is being operated for several large shale beds that are of special value in the manufacture of brick and terra cotta. The coal beds are worked in conjunction with the shale in order to supply fuel for burning the clay. In descending order the beds are known as Nos. 2, 3, 4, 5, and 6. They strike N. 70° W. and dip from 60 to 70° S. The formation is badly broken by igneous intrusions which follow the coal beds for some distance, parallel them in the shale, or cut across the coal at various angles. Wherever the igneous rock comes in contact with the coal it is altered more or less to natural coke. The igneous rock is either rhyolite or andesite, and is more or less decomposed. It makes excellent brick of delicate tints, and is used when encountered in the coal beds, so that the cost of mining the coal is not increased by its presence. The following sections were taken where the samples were obtained:

Sections of coal beds in Denny-Renton mine.

No. 9173, bed No. 2.

	Ft.	in.
Scale, carbonaceous.		
* Coal	3	8½
Coal, bony.		

No. 9172, bed No. 4.

	Ft.	in.
Shale, black.		
Shale, carbonaceous		2½
* Coal	2	8½
Shale.		
	2	11

No. 9175, bed No. 6.

	Ft.	in.
Shale, carbonaceous.		
* Coal, irregular streaks of "sulphur"	2	2½
Shale, brown		1
* Coal	2	5
Shale, black, carbonaceous (poor floor).		
	4	8½

No. 518-D, bed No. 5.[1]

	Ft.	in.
* Coal		5½
Shale		1
* Coal	1	1
"Rash"		1½
* Coal	2	1
Coal, bony.		
	3	10

No. 9176, bed No. 3.

	Ft.	in.
Shale, carbonaceous.		
* Coal, slightly bony		6
Shale, brown, hard		1
* Coal, one-third badly squeezed		8½
Shale, hard		2½
* Coal,, lime in joints		11
Shale, brown		1
* Coal	1	3½
Shale, carbonaceous (poor floor).		
	3	9½

No. 9174, bed No. 5.

	Ft.	in.
Shale, black, carbonaceous.		
* Coal	1	11
"Niggerhead"		3
* Coal	1	11
Shale, black, carbonaceous (poor floor).		
	4	1

No. 519-D, bed No. 4.[1]

	Ft.	in.
* Coal	2	3½
Coal, bony		4
	2	7½

No. 520-D, bed No. 5.[1]

	Ft.	in.
* Coal		5
* Shale and sandstone		¼
* Coal		5¼
Shale and sandstone		1
* Coal		1½
"Rash"		2¼
* Coal	1	11
	3	2¼

[1] Washing and coking tests of coal, Bull. Bureau of Mines No. 5, 1910, pp. 13-14.

Preparation for market.—The coal from all the beds is mixed at the bunker and picked by hand. The small coal is then washed through a Jeffery tub washer, so that most of the partings and all the "sulphur" balls are removed from the coal.

Samples for analysis.—Sample 9173 was taken from bed No. 2 in a small crosscut from bed No. 3 about 2,600 feet due north of the south quarter corner of sec. 3, T. 22 N., R. 7 E. It is overlain by carbonaceous shale and underlain by bony coal, both of which mix to some extent with the coal in mining and must be separated. Sample 9176 was taken from bed No. 3 about 50 feet west of the place where sample 9173 was obtained. The bed contains three layers of shale, which can be separated by careful picking and washing and which were not included in the sample. The roof and floor are of carbonaceous shale; both are more or less crushed and break off very readily. The floor of the mine is especially poor, and some places as much as a foot of the shale mixes with the coal, so that the output from this bed should be very carefully picked and washed. Sample 9172 was taken from bed No. 4 in chute 29 of the east gangway. The bed is overlain by about 2 inches of carbonaceous shale, which breaks with the coal and must be separated at the bunker. Sample 9174 was taken from chute 27, about 45 feet above the east gangway on bed No. 5. A layer of pyrite near the center of the bed can be separated at the bunker, and this impurity was not included in the sample. The bed also contains scattered through the coal small nodules of pyrite, which may be removed by washing. The roof of this mine is of strong carbonaceous shale, but the floor is badly broken carbonaceous shale, and this shale mixes with the coal in mining.

Samples 518–D, 519–D, and 520–D were taken in 1908 by Karl M. Way in connection with two cars of coal shipped from this mine to the United States Geological Survey for testing purposes. Sample 518–D was obtained from coal bed No. 5 at a point in the mine 2,400 feet northeast of the drift mouth. Sample 520–D represents the same bed of coal and was obtained at a point 3,000 feet northeast of the drift mouth. Sample 519–D was obtained from coal bed No. 4 at a point 1,500 feet northeast of the mouth of the mine. Sample 585–D represents a car of run-of-mine coal from bed No. 4, and 586–D represents a car of the same kind of coal from bed No. 5. Sample 6485 was taken from bed No. 5. Sample 9175 was taken from chute 5 about 25 feet above the east gangway on bed No. 6. The bed contains one shale parting and numerous small nodules of pyrite which can be separated by careful picking and washing and were not included in the sample. The roof of this bed is of carbonaceous shale, and is fairly firm. The bottom is of badly broken carbonaceous shale which slabs off to a depth of about 1 foot in places and must be separated from the coal. The analyses of the samples are given on pages 53–54.

Character and quality of the coal.—The coal from beds Nos. 4, 5, and 6 is pitch black, gives a dark brown streak, and has a vitreous luster. It is minutely jointed, banded, and laminated, and breaks with an irregular fracture. It contains a small amount of moisture, and does not weather on exposure to the air. It has a moderate amount of ash and the same heating value as the average coal from the vicinity of Bayne and Occidental. Coal from bed No. 3 resembles that from Nos. 4, 5, and 6. Owing to its higher amount of ash, it has a correspondingly lower heating value than other coals from the same mine. This coal has also a greater amount of sulphur than that found in the other beds. The coal from bed No. 2 is pitch black has a reddish-brown streak and a slightly vitreous luster. It is massive, banded, and laminated, and breaks with an irregular splintery fracture. It contains about the same amount of ash as the other beds and compares in heating value with coal from mine No. 1 at Ravensdale.

PROSPECTS SOUTHEAST OF ISSAQUAH.

Prospects in the Tiger Mountain district, about 6 miles southeast of the Northern Pacific Railway at Issaquah. No. 33.

Kind of coal: Bituminous.

Coal beds.—The beds are exposed on the north side of a ravine in a densely wooded country. Their relation to beds in other parts of the county is not definitely known, for they are more or less broken by faults and intrusions of igneous rock and the outcrops are very limited. The beds strike N. 43° E. and dip 44° NW. The following sections were measured where the samples were obtained:

Sections of coal beds in prospects in Tiger Mountain district.

No. 9290.

	Ft.	in.
Shale, compact.		
Shale, slaty		6
*Coal	2	2
Clay, dark, plastic		2
*Coal	1	8½
Clay, white, plastic		11
Coal, dirty		11
Clay, shaly		3
Sandstone, massive, white.		
	6	7½

No. 9289.

	Ft.	in.
Sandstone, massive, white.		
Shale, carbonaceous		5
*Coal		4
Shale, brown, soft		3
*Coal		2
Pyrite		1
*Coal		9
Clay, brown		2
*Coal		6
Clay		1
*Coal		4
Clay, sandy		2
Coal		6
Sandstone, massive, white.		
	3	9

Samples for analysis.—Sample 9290 was taken from the larger and better of the two beds. The coal is so badly crushed that it could be crumbled almost to a powder in the hand. A parting of clay which occurs near the center can be separated from the coal and was not included in the coal. Sample 9289 was taken a short distance down the stream from No. 9290 in the other bed. This bed contains several thin partings which can be separated from the coal, and they were not, therefore, included in the sample. The analyses of these samples are given on page 54.

Character and quality of the coal.—The coal from the prospect highest on the creek is pitch black, with a black streak and a vitreous luster. It is massive and dense, and breaks with an irregular fracture. It contains a moderate amount of moisture, probably absorbed from the overlying soil, which is given off readily on air drying. It has a moderate amount of ash and compares in heating value with the average bituminous coal of the State. The coal from the lowest prospect is pitch black and has a reddish-brown streak. It is banded and laminated, and breaks with an irregular splintery fracture. It contains about the same amount of moisture and a greater amount of ash than that of the other bed and a correspondingly lower heating value. The amount of sulphur in the coal is greater than that of most of the Washington coals. Both coals should be classed as bituminous.

PROSPECT SOUTHWEST OF PRESTON.

Prospect about 1 mile southwest of Preston. No. 34.

Coal bed.—The bed is very poorly exposed, and its relation to other beds in the vicinity is not known. The following section was taken at the end of a small drift run on the bed about 25 feet.

Section in prospect southwest of Preston.

No. 8546.

	Ft.
Coal and shale, mixed.	
*Coal, badly broken	3±
Coal and shale mixed.	

Sample for analysis.—Sample 8546 was taken from the bench of crushed coal here exposed. The joints of the coal were filled with mud from the overlying soil and the sample was washed to remove the mud. It was sealed in the can while still wet and the analysis should show a higher amount of moisture than if the sample had been dry. The analysis of the sample is given on page 54.

Character and quality of the coal.—The coal is so high in ash and sulphur that it is of no economic value. The relation of volatile matter to fixed carbon indicates that this is a semibituminous coal, but taken as a whole the bed can hardly be considered more than carbonaceous shale.

NIBLOCK.

Niblock, a series of water level drifts about 1½ miles southwest of Snoqualmie, on a spur of the Northern Pacific Railway. No. 35.

Operator: United Collieries Co., Seattle, Wash.

Kind of coal: Bituminous (coking).

Coal beds.—Four coal beds have been worked at this mine at different times. The mine has not been in operation for several years, but it will probably be reopened in a short time. At the time of the writer's visit beds Nos. 3, 4, and 5 were the only ones from which samples could be obtained. The coal measures strike N. 13° E., and dip rather steeply to the west. Bed No. 4 lies about 100 feet stratigraphically above No. 3, and bed No. 5 about 60 feet above No. 4. The following sections were measured where the samples were obtained:

Sections of coal beds in Niblock mine.

No. 10031, bed No. 3.

	Ft.	in.
Coal, very finely jointed	1	
Shale, soft		6
Shale and clay, mixed		8
*Coal, bright, clean	4	
Shale, carbonaceous.		
	6	2

No. 10032, bed No. 4.

	Ft.	in.
Sandstone, shaly.		
*Coal, clean, bright	1	1½
Clay		¾
*Coal, clean	1	4
Shale, carbonaceous		¾
*Coal		8½
Shale, black, carbonaceous, with coal, bottom.	3	3½

No. 10033, bed No. 5.

	Ft.	in.
Bone		2
*Coal, bright	1	9
Bone		1
*Coal, clean, bright		10
Shale, carbonaceous		2
*Coal	2	5
Coal, bony		4
Coal, soft		1
	5	10

Preparation for market.—The beds are too highly inclined and the coal too finely jointed and broken to admit of the separation of impurities in the mine. The coal was picked and washed at the bunker, and the best washed coal was used at the coke ovens on the property. A new bunker and washer is being installed by the United Colliery Co. at Seattle, and to this bunker all the coal will be shipped for cleaning and preparation for the market after it has passed the picking table. Much of the coal will be manufactured into briquets.

Samples for analysis.—Sample 10031 was taken from bed No. 3 about 25 feet up a chute 500 feet from the entrance to the highest water level on this bed. The bed is overlain by soft shale mixed with clay, and by a layer of finely jointed coal. A good sample could not be obtained from this upper layer of coal, and therefore only the main bench of coal was sampled. The bed is overlain and underlain by soft carbonaceous shale, which mixes to a considerable extent with the coal, and must be removed in preparing the coal for the market. Sample 10032 was taken from bed No. 4 on the middle water level where the rock tunnel from bed No. 5 to bed No. 3 crosses bed No. 4, at a point about 800 feet from the entrance to the tunnel on bed No. 5. The two partings in this bed can be separated by careful picking and washing, and were not included in the sample. Sample 10033 was taken from bed No. 5 at the junction of the main rock tunnel to No. 5 with the gangway on the coal, at a point about 160 feet from the entrance to the mine. The bed contains several partings, which can be separated from the coal by careful picking and washing and which were not included in the sample. The analyses of these samples are given on page 55.

Character and quality of the coal.—The coal from this mine is pitch black, with a nearly black streak and a vitreous luster. It is dense and breaks with an irregular cubical fracture, but owing to its minute joints it crumbles very readily, so that the proportion of lump coal is very small. The amount of moisture is small, and the coal does not slack when exposed to the air. Samples from bed No. 5 show a large amount of ash, but it is possible that much of this ash may be removed by very careful washing. The coal is considered one of the best coking coals in the State, and has also been used not only in making coke, but to some extent as blacksmith coal.

KITTITAS COUNTY.

The extent of the Roslyn coal bed on the northeast side of the field is well known, for it has been worked nearly the full length of the field along this side of the syncline in the mines of the Northwestern Improvement Co., but the southwest edge of the field is covered by gravel, and the geology of the coal-bearing formation is therefore obscure. One bed of known workable thickness underlies the Roslyn bed, but its extent and value have not been determined. The structure of the northwest end of the field is believed to be complicated by faults and folds, but it is thought that a part of the structure can be worked out by careful field examination.

The principal coal bed of this field, the Roslyn, changes considerably in character and quality from the southeast end of the field, near Clealum, to the northwest end, near Beekman. Near Clealum the coal is banded and laminated, and breaks with an irregular splintery fracture, so that it resembles very closely some of the layers of bony coal which it contains. At the northwest end of the field the coal is either dense or only slightly laminated, breaks with an irregular cubical fracture, and is more jointed and more friable than that at the southeast end. The amount of ash in the clear coal at Clealum is considerably greater than at Beekman, and the heating value is correspondingly lower. A considerable difference in coking properties is also reported; the coal at Clealum shows only slight coking tendencies, whereas that at Beekman makes a fair coke. Investigation indicates that this change in coking quality takes place between Clealum and Roslyn and coincides approximately with the change in the character of lamination of the coal. Of the change in the Roslyn bed, George Otis Smith[1] makes the following statement: "These analyses, which were furnished by L. S. Storrs and are given below, show the variation in this seam from a lignitic, noncoking coal to a fairly good coking coal." The term lignite as used in the preceding quotation was applied to almost all the western coals now known as subbituminous, and even to some of the lowest grades of true bituminous coal.

Gas occurs in considerable quantities in the coal and in the overlying rocks. It works out gradually as the gangways and rooms are being driven, or comes from the roof in the form of small blowers. Several small explosions and two large ones have resulted from the gas. In some of the mines the workings are very dry; the coal crumbles readily and makes a large amount of dust, which accumulates on the ribs and mine timbers. This dust, like the coal, is high in volatile matter, and very inflammable, and will explode with great violence when mixed with the proper proportion of air. In order to guard against such explosions, the gangways in most of the lower workings are sprinkled several times a week. A small gas explosion at a time when the mine is dry and filled with dust would probably produce very serious results. It is the belief of the investigators of the United States Geological Survey, the State inspector of mines, and the mine officials that the violent explosion at shaft No. 4, at Roslyn, on October 3, 1909, was brought about through those conditions.

The coal of the Roslyn field is low in moisture, and does not slack or crumble by weathering during transportation or storage. No preparation for market is given the coal beyond the separation of the thicker partings, and the "sulphur" balls in the mine and the picking of the lump coal at the tipple, but the percentage of ash would be much smaller if the coal could be thoroughly picked and washed after coming from the mine. The coal mined by the Northwestern Improvement Co. is not cleaned except in mining, and carload samples would doubtless show a percentage of ash considerably higher than those given in the analyses accompanying this report.

The samples collected from this county by the writer were obtained in November, 1909. Analyses of five samples collected from Roslyn and Beekman by other members of the Survey are included for the purpose of comparison.

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[1] Mount Stuart folio (No. 106), Geol. Atlas U. S., U. S. Geol. Survey, 1904, p. 10; Snoqualmie folio (No. 139), Geol. Atlas U. S., U. S. Geol. Survey, 1906, p. 13.

PROSPECT, NORTHWEST OF BEEKMAN.

Prospect, about 1½ miles northwest of Beekman.[1]

Kind of coal: Bituminous (?).

Coal bed.—The bed strikes N. 55° E. and dips 12° SE. It is believed to underlie the principal bed of the Roslyn field. It is too thin to be of commercial importance. The following section was measured at the end of a 25-foot drift driven on this bed:

Section of coal bed in prospect 1½ miles northwest of Beekman.

No. 9404.

	Ft.	in.
Shale, hard	1+	
*Coal	1	2½
Shale		2½
Coal		2½
Shale, soft		7
	3	2½

Sample for analysis.—Sample 9404 was taken where the above section was measured. The layers of coal and shale associated with the main bed were so badly weathered that their behavior under average mine conditions could not be determined. The analysis of the coal is given on page 55.

Character and quality of the coal.—The sample collected was somewhat weathered. A sample of unweathered coal from this bed would probably show a higher grade of coal than that indicated by the analysis. The coal should probably be classed as low-grade bituminous.

LAKEDALE.

Lakedale, a water-level mine 1 mile northwest of Beekman, on a spur of the Northern Pacific Railway. No. 36.

Operator: Consolidated Coal Co., Yakima, Wash.

Kind of coal: Bituminous.

Coal bed.—The coal bed worked in this mine strikes N. 80° E. and dips 10° S. Some investigators have thought this bed to be the Roslyn bed or the bed underlying the Roslyn, but comparison of the section with those of the Roslyn bed given in the following descriptions, or with that of the bed measured at the prospect on the property of the Roslyn-Cascade Coal Co. (p. 136) will show that this is probably a third bed. It is believed to underlie both the Roslyn beds exposed farther east. The section following was measured at the place where the sample was taken.

[1] Not represented on Pl. III.

Section of coal bed in Lakedale mine.

No. 9405.

	Ft.	In.
Shale, carbonaceous, black.		
*Coal, bony near center	1	
Shale		6½
*Coal		6½
*Shale, hard		1
*Coal		7½
*Coal, bony		¼
*Coal		9¼
Shale, hard, brown.		
	3	7

Preparation for market.—The partings can be removed to some extent in mining, but most of the remaining impurities is removed at the tipple by picking as the coal passes over bar screens.

Sample for analysis.—Sample 9405 was taken 10 feet above the gangway, about 150 feet from the entrance. The bed contains two bony layers in the lower part which can not be readily separated from the coal, and which were therefore included in the sample. The shale parting between the upper and the lower benches can be separated in preparation for market, and was, therefore, not included. Both the roof and the floor are firm and do not mix with the coal. The analysis of this sample is given on page 55.

Character and quality of the coal.—The coal is pitch black and has a dark-brown streak. It is massive and laminated and breaks with a cubical fracture. In general, the coal resembles that of the Roslyn bed at the west end of the field. It contains a small percentage of moisture and will not weather while being transported to market. The high percentage of ash is due to the presence of the two bony layers of the lower bench. The coal is classed as bituminous.

BEEKMAN.

Beekman, a slope at Beekman, about 3 miles northwest of Roslyn on the Northern Pacific Railway. No. 37.

Operator: Roslyn Fuel Co., Seattle, Wash.

Kind of coal: Bituminous.

Coal bed.—The Roslyn bed is the only one worked at this mine. In the eastern part of the workings it strikes N. 70° W. and dips 14° SW. Near the end of the west gangways the bed turns south, so that it strikes S. 75° W. and dips 8° SE. Several partings, which vary in character and position in different parts of the mine, are present in the bed. The roof and floor of the mine are very firm, and do not mix with the coal in mining. Shale occurs in a layer 1 or 2 inches thick between the coal and the roof and mixes to some extent with the coal, but can be separated in mining and in preparation for market.

The following sections were measured at the points where the samples were taken:

Sections of Roslyn coal bed in Beekman mine.

No. 9411.

	Ft.	in.
Shale	2+	
Shale, soft		1
*Coal	1	3
*Shale, little "sulphur"		¼
*Coal	1	2½
Shale, hard		½
*Coal		3
*Shale, hard		¼
*Coal		2½
Shale, hard		1
*Coal	1	8½
Shale, hard		1
*Coal		2½
Shale, sandy.		
	7	2+

No. 9412.

	Ft.	in.
Shale		1+
*Coal	2	6
*Shale, brown, carbonaceous		1
*Coal		2
*Coal, bony		½
*Coal	1	1½
*Shale		1
*Coal		5½
Shale, hard.		
	4	6½+

No. 9413.

	Ft.	in.
Shale	2+	
Shale, streak of coal		1
*Coal	1	1
*Coal, bony		½
*Coal	3	1
Shale, hard		1
*Coal		2
Shale, hard, carbonaceous.		
	6	6½+

No. 9414.

	Ft.	in.
Shale	1+	
Shale, soft		1
*Coal	2	5
*Shale, hard		½
*Coal		3½
*Shale, hard		½
*Coal	1	9½
Shale, hard		1
*Coal		2½
Shale, hard		3½
	6	3+

No. 9415.

	Ft.	in.
Shale.		
Shale, soft		1½
*Coal	1	3½
*Shale, bony		½
*Coal	1	2½
*Shale, bony		½
*Coal		3
*Sandstone, "sulphur" band		¼
*Coal		5
*Shale, bony		¼
*Coal	1	9½
Shale, bony		4
Shale.		
	5	6½

No. 550-D.[1]

	Ft.	in.
*Coal		1
*"Mother coal"		¼
*Coal	2	3
Shale		1
*Coal		4
Shale		¾
*Coal		6¼
Shale		¾
*Coal	1	1½
Shale		½
*Coal		2
Shale.		
	4	9

No. 551-D.[1]

	Ft.	in.
*Coal	2	9½
Shale, hard		¾
*Coal	1	10
Shale		½
*Coal		1½
Shale.		
	4	10¼

[1] Washing and coking tests of coal: Bull. Bureau of Mines, No. 5, p. 16.

Preparation for market.—Only the larger "sulphur" balls and local enlargements of the partings are removed at the mine. At the tipple the coal is passed over shaking screens having 1¾-inch and 3-inch perforations; the oversize is picked as it is loaded into the railroad cars, and the undersize from the 1¾-inch and 3-inch screens are sold as steam coal and as egg coal, respectively.

Samples for analysis.—Sample 9411 was taken on the gangway of the second level west between rooms 26 and 27. At this place the bed contains five thin partings, three of which are over one-fourth inch in thickness and can be separated from the coal by picking. These three partings were therefore not included in the sample. Sample 9412 was collected at the end of the gangway on the second level east near the property line. Three thin partings were found at this place, but they resemble the coal so closely that they can not be readily separated, and were therefore included in the sample. Sample 9413 was collected 150 feet beyond room 21 on the gangway of the third level east. One parting of bony coal near the bottom of the bed was removed from the sample. Sample 9414 was obtained between rooms 17 and 18 on the gangway of the third level west. The three shale partings do not differ very materially from the coal, and it was thought that by removing the largest of these partings the resulting amount of ash in the sample would represent the amount of ash in the coal after picking. Sample 9415 was obtained at the foot of the slope, about 250 feet below the fourth level gangway. Several thin partings in the bed could not be separated readily by picking and were included in the sample. Sample 9410 was obtained from the surface of a railroad car after the coal had passed through the shaking screen with 1¾-inch perforations. The best coal from the mine is much jointed and breaks very readily, so that a considerable percentage of the output passes through 1¾-inch holes. The fragments of the partings as they come from the mine are too large to pass through these holes, and in consequence examination of the coal on the surface of the car shows almost clean coal and a very small percentage of shale or bone. It is believed that the shale partings can be better separated from the fine coal by the shaking screen than by washing or picking. Analysis 9459 represents a composite sample consisting of equal portions of all the samples collected by the writer from this mine. Samples 550–D, 551–D, and 693–D were taken by Karl M. Way, of the United States Geological Survey; sample 550–D from the face of the main slope, 1,000 feet southwest of the entrance to the mine, sample 551–D on the second level west, 1,300 feet southwest of the entrance, and sample 693–D from a car of coal shipped to Denver, Colo., for testing. The analyses of the samples are given on pages 55–56.

Character and quality of the coal.—The coal is pitch black and has a dark-brown streak. It is massive and slightly laminated and breaks with a cubical fracture. If the coal is so carefully picked as to remove all nodules or lenses of pyrite over 2 inches in maximum diameter and one-half inch in thickness, the picked coal should contain a very low percentage of sulphur. It has a heating value nearly as high as that of the best coal of King and Pierce counties, and equals in this respect much of the Alabama and Kentucky coal.

BUSY BEE.

Busy Bee, strip pit 2½ miles northwest of Roslyn. No. 38.

Operator: Busy Bee Coal & Improvement Co., Roslyn, Wash.

Kind of coal: Bituminous.

Coal bed.—The coal bed lies only a few feet beneath the surface throughout most of this property. A steel scraper, operated by wire cables from a logging engine, has replaced the ordinary horse scraper previously used in removing the material overlying the coal bed. A sample of the coal was taken and the following section of the coal bed measured where the cover had been about 6 feet thick:

Section of Roslyn coal bed in Busy Bee strip pit.

No. 9406.

	Ft.	In.
Sandstone, yellow.		
Shale	3	2½
Coal (weathered)		7
*Coal		9½
Coal, soft, with layers of shale		1
*Coal	1	3
Shale		1
*Coal		3½
Shale		½
*Coal		9½
Coal		7
Shale.		
	7	8½

Preparation for market.—The coal is passed over a 2½-inch bar screen. The oversize is picked and sold as lump, and the undersize is sold as steam coal.

Sample for analysis.—Sample 9406 was taken where the section given above was measured. The three partings can be removed from the coal by picking and were not included in the sample. About 7 inches of the upper portion of the bed was weathered and was not included in the sample. The lower 7 inches of the bed was not exposed. The analysis of the sample is given on page 56.

Character and quality of the coal.—The coal is pitch black and has a dark-brown streak. It is massive and laminated and breaks with a cubical fracture. This sample is lower in ash and has a higher heating value than any sample collected from the Roslyn bed in other parts of the field, but this fact does not necessarily mean that the coal is better here than elsewhere, because the entire thickness of the bed was not sampled.

PATRICK–M'KAY.

Patrick–McKay, slope 2½ miles northwest of Roslyn on the Northern Pacific Railway. Nos. 39 and 40.

Operator: Roslyn-Cascade Coal Co., Bellingham, Wash.

Kind of coal: Bituminous.

Coal bed.—The Roslyn bed is the only one at present operated on this property. It strikes N. 75° W. and dips 9° SW. The lower 2 inches of a 3-foot layer of shale between the bed and the overlying sandstone breaks after the coal is removed and is thrown into the gob, but the rest forms a good roof throughout most of the mine. The floor is firm and does not mix with the coal. A second bed 3½ feet thick is exposed 260 feet vertically below the outcrop of the Roslyn bed on this property and in prospects to the east on the north side of the ridge northeast of Roslyn, but the prospects were caved and neither sections nor samples could be obtained. The following sections of the Roslyn bed were measured at the points from which the samples were taken:

Sections of Roslyn coal bed in Patrick-McKay mine.

No. 9418.

	Ft.	in.
Shale.		
* Coal	1	3
* "Sulphur" band		¼
* Coal	1	1
* "Sulphur" band	Trace.	
* Coal		3
Shale, hard		1
* Coal	1	10
Shale.		
	4	6¼

No. 9417.

	Ft.	in.
Shale (good roof).		
Shale		2½
* Coal	1	2
* "Sulphur"	Trace.	
* Coal	1	3½
* Coal, bony		½
* Coal		2
Shale		1
* Coal	1	5½
Shale, hard		1
Shale.		
	4	6

No. 9416.

	Ft.	in.
Shale.		
Shale, soft		2½
* Coal	1	2
* "Sulphur" band		¼
* Coal	1	3
* Shale, hard		¼
* Coal		2½
Shale		1
* Coal	1	3½
Shale.		
	4	3

No. 9407, lower bed.

	Ft.	in.
Sandstone, yellow, massive.		
Shale	4	
Coal, bony	1	5½
Sandstone		1½
* Coal		8
Shale, hard		½
* Coal	1	5½
Shale		3½
Shale, hard		2
* Coal		9
Shale.		
	8	11

Preparation for market.—The coal is passed over bar screens with ⅞-inch and 1½-inch spaces. The oversize is picked and sold as lump coal, while the undersize is sold as steam coal.

Samples for analysis.—Sample 9418 was taken on the gangway of the first water level west at the entrance to room 18. Two "sulphur" bands, too thin to be separated by picking, are present, but a parting of bony shale in the lower part of the bed can be readily removed by picking and was not, therefore, included in the sample. Sample 9416 was taken from the west side of the slope, 50 feet above the entrance to the first water level east. The lowest shale parting of the bed, which is the only one that can be readily separated in preparation for market, was not included in the sample. Sample 9417 was taken at the end of the gangway on the first water level east, about 1,000 feet from the rock tunnel to the main slope. The lowest shale parting is the only one which can be separated by picking, and this parting is therefore not included in the sample. Analysis 9460 was made of a composite sample consisting of equal parts from samples 9418, 9416, and 9417. Sample 9407 was taken from the lower bed on this property, about 1,300 feet north of the center of sec. 6. The coal occurs in two benches separated by 5½ inches of shale, which can be used as a "mining." The bony coal overlying the upper bench has been considered to be of workable quality, but judging from its weathered appearance it probably contains more than 40 per cent of ash, and if mined and sold with the two other benches the coal from these benches would probably lose much of its commercial value. This bench may, however, prove to be of economic value in other parts of the field. The analyses of these samples are given on pages 56-57.

Character and quality of the coal.—The coal of the Roslyn bed is pitch black, massive, and very slightly laminated and breaks with an irregular fracture. It has about the same heating value as the coal from the same bed in the northwest end of the field. The coal of the lower bed is pitch black, massive, and slightly laminated and breaks with an irregular fracture. It contains a small amount of moisture and does not slack when exposed to the sun, but analysis of the coal shows a somewhat larger percentage of ash and sulphur than the average of the Roslyn coal. It resembles the best coal of the Roslyn bed in the western end of the field.

ROSLYN NO. 3.

Roslyn No. 3, incline, slope, and shaft mine at Ronald, 1½ miles northwest of Roslyn, on the Northern Pacific Railway. No. 41.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal bed.—The Roslyn bed, which is the only one worked in this mine, has about the same thickness here as elsewhere in the field. About 3 feet of shale lies between the bed and the overlying sandstone. Of this layer the lower 2 to 6 inches breaks after the coal is removed and is thrown into the gob, but the remainder forms a good roof throughout most of the mine. The floor of the mine is firm and does not mix with the coal. The sections following were measured at places where the samples were obtained.

Sections of the Roslyn coal bed in Roslyn No. 3 mine.

No. 9428.

	Ft.	In.
Shale.		
Shale, crushed.		
* Coal	2	3
"Sulphur" and shale		1
* Coal		6
* Coal, shaly, crushed		1
* Coal	1	4
Shale.		
	4	3

No. 9429.

	Ft.	In.
Shale.		
Shale, crushed	1	
* Coal	1	3½
* "Sulphur" band		½
* Coal	1	1
Shale (little "sulphur")		½
* Coal		2½
Shale		½
* Coal	1	5½
Shale.		
	5	2

No. 9430.

	Ft.	In.
Shale.		
* Coal	1	8
* "Sulphur" band		½
* Coal		9½
Shale		½
* Coal	1	10
Shale, hard, carbonaceous.		
	4	4½

No. 9431.

	Ft.	In.
Shale.		
Shale, falls easily (gobbed)		7
* Coal	1	3
* "Sulphur" band		½
* Coal	1	3½
Shale		½
* Coal		3½
† Shale, hard		½
* Coal	1	8½
* Coal, bony		½
* Coal		5½
Shale.		
	5	9

No. 9432.

	Ft.	In.
Shale.		
Shale, soft		1
* Coal	1	
* Coal with "sulphur" band		½
* Coal	1	3
Shale		1
* Coal		3
* Shale, hard		½
* Coal	1	5½
Shale, hard		1
Shale.		
	4	3½

Preparation for market.—The partings that separate freely from the coal in the mine and the rock that falls from the roof are thrown into the gob when the cars are loaded. The coal is not picked at the tipple, because it is clean enough for locomotive use.

Samples for analyses.—Sample 9428 was taken on the old fifth water-level gangway west, at the entrance to room 48. One parting near the center of the bed can be separated by picking and was not included in the sample. Sample 9429 was taken on the old sixth water-level gangway, between rooms 6 and 7, east of new slope 3. The two lower partings can be removed from the coal by picking and were not included in the sample. Sample 9432 was taken from the first level west, about 150 feet from the gangway up room 3 of the fourth battery. Three bands of impurities are present, of which only the center one is large enough to be separated by picking; this parting was not included in the sample. Sample 9431 was taken from the face of room 12 of the third battery on the first level west, 100 feet from the gangway. Only a part of the shale from the four partings in the bed can be separated by picking. An additional 5½ inches of coal at the bottom of the bed in this part of the mine is spoken of by the miners as a "swamp." Sample 9430 was collected on the east side of the manway between the foot of the shaft and the third level, 150 feet up slope from the base of the shaft. The lower parting can be separated by picking, and was not included in the sample. Analysis 9463 was made from a composite sample containing equal portions of all the samples collected from this mine. Analyses are given on page 57.

Character and quality of the coal.—In general the coal is pitch black, massive, and slightly laminated, and breaks with a cubical fracture, though a part of it is slightly banded and breaks with a splintery fracture. It has about the same heating value as that obtained from other mines in the northwest end of the Roslyn field.

ROSLYN NO. 2 SLOPE.

Roslyn No. 2, drift and slope mine at Roslyn, on the Northern Pacific Railway. No. 42.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal bed.—This mine is operated on the Roslyn bed, which strikes about N. 70° W. and dips about 12° S. At the top of the bed a layer of shale 3 feet thick separates the coal from a massive layer of sandstone. Fragments of this shale, the largest a foot in thickness, break after the coal is mined and are thrown into the gob. Occasionally they break with the coal and must be separated before the mine cars are loaded. The floor is firm and does not mix with the coal. The following sections were measured at the places from which the samples were taken:

Sections of Roslyn coal bed in Roslyn No. 2 slope.

No. 9433.

	Ft.	in.
Sandstone.		
Shale		7
Shale, carbonaceous		2½
* Coal, streaks of "sulphur"	2	6
Shale		1
* Coal		3
Shale		1
* Coal	1	10
Shale, hard.		
	5	6½

No. 9434.

	Ft.	in.
Sandstone.		
Shale (good roof).		
Shale (put in gob)	1	
* Coal, streaks of "sulphur"	1	1
* Shale, "sulphur" band	Trace.	
* Coal, streaks of "sulphur"	1	½
* Shale	Trace.	
* Coal		4
Shale		1
* Coal	2	
Shale.		
	5	6½

No. 9435.

	Ft.	in.
Shale.		
Shale, soft		2½
* Coal	1	
† "Sulphur" band mixed with coal		½
* Coal	1	3
Shale		½
* Coal		3
* Shale, soft		½
* Coal		3
Shale		½
* Coal	1	
* Shale		½
* Coal		7
Shale.		
	4	9

No. 9436.

	Ft.	in.
Shale.		
* Coal	2	6
* "Sulphur" band		¼
* Coal		1
Shale		1
* Coal	1	6
(?)		
	4	2¼

Preparation for market.—The partings which separate freely from the coal in the mine and the rock "falls" from the roof are thrown into the gob when the cars are loaded. The coal is not picked at the tipple, because it is clean enough for locomotive use.

Samples for analysis.—Sample 9433 was taken on the fifth level west from slope No. 2, about 250 feet up room 7 of the second block. Both shale partings of the bed can be separated by picking and were not included in the sample. Sample 9434 was taken on the sixth level west from slope 2 on the side of the barrier pillar separating this mine from mine No. 3, and 360 feet up the rise from the gangway. Only the lowest shale parting is of sufficient size to be separated by picking, and this parting was not included in the sample. Sample 9435 was collected on the sixth level west from slope 2 on the gangway between rooms 2 and 3. The bed contains five partings, and it would be difficult to remove more than half of the impurities resulting from these partings. In order to obtain a representative amount of ash the lowest parting and one-half of the first parting below the top were separated from the sample. Sample 9436 was taken from the side of the slope between the eighth and tenth levels, west from shaft 4, about 10 feet below the air course below the eighth level. The lower part of the bed was not exposed on account of rock "falls," and the condition of the mine atmosphere was so poor that time could not be taken to obtain a full section. The lower parting, which is the only one of sufficient size to be separated by picking, was not included in the sample. Analysis 9464 was made of a composite sample consisting of equal parts of samples 9433, 9434, 9435, and 9436. The analyses of these samples are given on page 58.

Character and quality of the coal.—The coal is pitch black, massive, and slightly banded, and breaks with an irregular fracture. The coal in the upper part of the bed contains thin irregular lenses of "sulphur," which could probably be easily separated from the coal by washing. These lenses were excluded from the samples, which, therefore, give small amounts of sulphur in the analyses. The coal has about the same heating value as that obtained from other mines in this part of the field.

ROSLYN NO. 2.

Roslyn No. 2, incline at Roslyn, on the Northern Pacific Railway. No. 42.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal bed.—This mine is operated on the Roslyn bed, which strikes N. 50° W. and dips about 12° S. About 3 feet of shale separates the bed from the overlying sandstone. The lower 2 inches of this shale breaks after the coal is removed and is thrown into the gob. The remainder forms a good roof throughout most of the mine. The floor of the mine is firm and does not mix with the coal. The following sections were measured at the places from which the samples were obtained:

Sections of Roslyn coal bed in Roslyn No. 2 mine.

No. 9442.

	Ft.	in.
Shale.		
Shale, soft		2½
* Coal	2	3½
* Shale		Trace.
* Coal		5
Shale, hard		2
* Coal	1	3
Shale.		
	4	4

No. 9443.

	Ft.	in.
Shale, hard.		
Shale, soft		2½
* Coal	2	3½
* Shale		¼
* Coal		2
* Shale, "sulphur"		Trace.
* Coal		5½
* Shale		½
* Coal	1	5
Shale, yellow.		
	4	7¼

No. 9444.

	Ft.	in.
Shale.		
* Coal	2	3
† "Sulphur" band		½
* Coal		3½
† Shale		¼
* Coal		3½
† Shale		½
* Coal	1	5
Shale, hard, carbonaceous		1½
Shale, yellow.		
	4	5¾

No. 2457.

	Ft.	in.
* Coal	2	10½
Parting		¾
* Coal	1	2¼
	4	1½

Preparation for market.—Partings and impurities which separate readily from the coal are removed at the mine, and the coal is used by Northern Pacific Railway locomotives without further picking at the tipple.

Samples for analysis.—Sample 9442 was taken from the eighth level about 15 feet west of the east rope slope. The lower parting of the bench was not included in the sample. Sample 9443 was taken from the seventh level west on the gangway at the entrance to room 80. All the partings in the bed are so thin that they can not be readily separated from the coal and were, therefore, included in the sample. Sample 9444 was taken on the tenth level east, 75 feet beyond room 43. By careful picking about half the material in the partings could be separated from the coal, and therefore only half of each parting was included in the sample. Analysis 9468 was made of a composite sample of equal parts of all the samples collected by the writer from this mine. Sample 2457 was collected by M. R. Campbell in 1905, about 6,000 feet from the entrance to the mine, and does not include one parting which occurs at this place. Analysis 3098 was made from a car sample of lump coal shipped for testing purposes from mine No. 2 at about the time sample 2457 was taken. The analyses of these samples are given on pages 58–59.

Character and quality of the coal.—Most of the coal is pitch black and massive, and breaks with a cubical fracture; the rest is slightly banded, and the fracture is somewhat splintery. It has about the same heating value as coal from the other mines in this vicinity.

A. & E.

A. & E., a drift and slope mine 1 mile northeast of Roslyn. No. 43.

Operator: Yakima-Roslyn Coal Co., Roslyn, Wash.

Kind of coal: Bituminous.

Coal bed.—The mine is on the Roslyn bed, which strikes N. 70° W. and dips 11° S. About 3 feet of shale lies between the coal bed and the overlying sandstone. The lower 2 inches of the shale breaks after the coal is removed and is thrown into the gob, but the rest forms a good roof throughout most of the mine. The floor of the mine is firm and does not mix with the coal. The following section was measured:

Section of Roslyn coal bed in A. & E. mine.

No. 9402.

	Ft.	in.
Shale.		
Shale, soft		2½
*Coal	2	5
Clay		½
*Coal		2½
Shale, black		½
*Coal	1	8
Shale, dark.		
	4	7

Preparation for market.—Partings, roof fragments, and other impurities which can be readily removed when the mine cars are loaded are thrown into the gob. At the tipple the coal is passed over a 3-inch bar screen, from which the oversize is sold as lump and the undersize as steam coal.

Sample for analysis.—Sample 9402 was taken 160 feet up the ninth room from the slope where the section given above was measured. Both the shale partings can be removed by careful picking, and were not included in the sample. The analysis of this sample is given on page 59.

Character and quality of the coal.—Most of the coal is pitch black, massive, and slightly laminated, and breaks with a cubical fracture. The remaining part is slightly banded and has a somewhat splintery fracture. It has about the same heating value as coal from the other mines in this vicinity.

ROSLYN NO. 6.

Roslyn No. 6, a series of drift mines at Roslyn, on the Northern Pacific Railway. No. 42.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal bed.—The mine is on the Roslyn bed, which strikes N. 65° W. and dips from 7 to 10° SW. About 3 feet of shale lies between the coal and the overlying sandstone; the lower 2 to 6 inches of this shale breaks after the coal is removed, and is thrown into the gob, but the rest forms a good roof throughout the major part of the workings. The floor of the mine is firm and does not mix with the coal. The following sections were measured at the places where the samples were taken:

Sections of Roslyn coal bed in Roslyn No. 6 mine.

No. 9439.

	Ft.	in.
Shale.		
Shale, soft		2½
*Coal	2	6½
†"Sulphur" band		¼
*Coal		1½
Shale		½
†Coal		1½
Shale		1
*Coal	1	1
*"Sulphur" band		¼
*Coal		6
Shale, hard		6½
	5	3½

No. 9440.

	Ft.	in.
Shale.		
Shale, soft		2½
*Coal	2	3½
Shale		1
*Coal		2½
*Shale, carbonaceous		¼
*Coal		4
Shale, hard		2
*Coal	1	8
Shale, hard.		
	4	11¾

No. 9441.

	Ft.	in.
Sandstone.		
Shale, slate-colored	2	1
*Coal, lenses of "sulphur"	2	8
Shale		½
*Coal		3
Shale		1
*Coal, lenses of "sulphur"	1	6½
Shale, sandy.		
	6	8

Preparation for market.—The partings and impurities which separate readily from the coal are removed in the mine, and as all the coal is used for locomotives it needs no further picking at the tipple.

Samples for analysis.—Sample 9439 was taken from the stump pillar between rooms 1 and 2 on the seventh level. In order to remove an amount of impurities equivalent to that which could be separated by careful picking, the two center partings, half the coal between them, and half the upper parting were not included in the sample. Both the shale partings were removed from sample 9441, which was taken at the east end of the seventh level, and the top and bottom partings were removed from sample 9440, taken from the east end of the fifth level. Analysis 9466 was made of a composite sample containing equal parts of all of the samples collected from this mine. The analyses of these samples are given on page 59.

Character and quality of the coal.—Most of the coal is pitch black and massive, and breaks with a cubical fracture, although a part is slightly banded and has a somewhat splintery fracture. The coal has about the same heating value as that of the other mines in this part of the country.

ROSLYN NO. 4.

Roslyn No. 4, a shaft 640 feet deep at Roslyn, on the Northern Pacific Railway. No. 44.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal bed.—This mine is on the Roslyn bed, which strikes N. 70° W. and dips 15° SW. Fragments from the lower 2 to 6 inches of a layer of shale about 3 feet thick separating the coal from the overlying sandstone break off after the coal is removed and are thrown into the gob. The rest of the shale forms a good roof throughout the greater part of the workings, and the floor of the mine is firm and does not mix with the coal. The following sections were measured at the places from which the samples were taken:

Sections of Roslyn coal bed in Roslyn No. 4 mine.

No. 9437.

Shale.	Ft.	In.
Shale, gobbed		7
Coal, streaks of "sulphur"		2½
*Coal, thin streaks of "sulphur"	2	5½
Shale		1
*Coal		3
Shale		½
*Coal	2	
Shale.		
	5	7½

No. 2458.

	Ft.	In.
*Coal	1	4½
"Sulphur" band		½
*Coal	1	4
Coal and shale		4
*Coal	1	9½
	4	10½

No. 9438.

Shale, roof.	Ft.	In.
Shale, gobbed		9½
*Coal	1	3½
Shale, containing "sulphur"		1
*Coal	1	5½
*"Sulphur" band		¼
*Coal		1½
Shale		1
*Coal	2	
Shale.		
	5	10¼

Preparation for market.—The partings and impurities which separate readily from the coal are removed in the mine, and as all the coal is used for locomotives it does not need further picking at the tipple.

Samples for analysis.—Sample No. 9438 was taken from the gangway on the eleventh level west, near the center of the second battery; the top and bottom partings are not included in the sample. Sample 9437 was taken from the gangway on the eleventh level east, between rooms 3 and 4 of the second battery, both partings being removed. Analysis No. 9465 was made from a composite sample containing equal portions of these two samples. Sample 2458 was collected by M. R. Campbell in 1905 from room 3 of the second battery, on the ninth level west, about 2,000 feet from the bottom of the shaft. Two partings occurred in the bed at this place, neither of which was included in the sample. The analyses of the samples are given on pages 59–60.

Character and quality of the coal.—The coal is pitch black and massive and breaks with a cubical fracture. In the mine it is under considerable pressure from the roof and is worked without shooting. It has about the same heating value as coal from the other mines in this part of the field.

ROSLYN NO. 5.

Roslyn No. 5, a slope mine 1½ miles southeast of Roslyn, on a spur of the Northern Pacific Railway. No. 45.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal bed.—The mine is on the Roslyn bed, which strikes N. 45° W. and dips from 20 to 30° SW. The coal is separated from a massive overlying sandstone by about 3 feet of shale, of which fragments ranging up to a foot in thickness break off after the coal in mined and are thrown into the gob. Occasionally they break with the coal and must be separated from it before the mine cars are loaded. The floor is firm and does not mix with the coal. The following sections were measured at the places from which the samples were taken:

Sections of Roslyn coal bed in Roslyn No. 5 mine.

No. 9427.

	Ft.	in.
Shale.		
Shale, with streak of coal		1
*Coal	2	6½
"Sulphur" band		1
Coal, crushed		1
Clay		1
*Coal	1	11
Shale, hard.		
	4	9½

No. 9424.

	Ft.	in.
Shale.		
*Coal	1	1
*Sandstone and "sulphur"		½
*Coal (middle 3½ inches is high in sulphur)	1	7
Sandstone and "sulphur"		½
*Coal		1
Shale		½
*Coal	2	5
Shale, carbonaceous.		
	5	3½

No. 9425.

	Ft.	in.
Shale.		
*Coal	1	3
*"Sulphur" band, irregular.	Trace.	
*Coal	1	2½
*"Sulphur"		¼
*Coal		1½
Clay		½
*Coal	2	3½
Shale, hard, carbonaceous.		
	4	11¼

No. 9423.

	Ft.	in.
Shale.		
*Coal	2	8
*Bone		1
*Coal		3
Clay, soft		½
*Coal	1	8½
Shale.		
	4	9

No. 9426.

	Ft.	in.
Shale.		
Shale, soft		3
*Coal	1	2
*Sandstone, "sulphur" band.		¼
*Coal	1	6
*"Sulphur" band		¼
*Coal		2
Clay, soft		1
*Coal		2
*Coal, bony		¼
*Coal	1	7
Shale, hard		5
Shale.		
	5	4¾

Preparation for market.—The partings and impurities which separate readily from the coal are removed in the mine, and as all the coal is used for locomotives it needs no further picking at the tipple.

Samples for analysis.—Sample 9427 was taken from the barrier pillar between mine No. 5 and old mine No. 1, at Roslyn and on the gangway of the first level west of slope 5. A 3-inch parting of crushed coal, clay, and pyrite, which occurs in the center of the bed, was not included in the sample. Sample 9423 was taken from the barrier pillar between mines No. 5 and No. 7, about 10 feet above the second level gangway of mine No. 5. The lower parting in the bed can be separated by picking, and was not included in the sample. Sample 9424 was taken on the third level west at the entrance to room 50. The two lower partings in the bed can be easily separated from the coal and were therefore not included in the sample. Sample 9426 was taken on the third gangway east at entrance to room 42. The bed contains four partings, all but one of which would be difficult to separate from the coal by picking, and only the second parting from the bottom was removed in the sample. Sample 9425 was taken from the air course below the fourth level, about 30 feet west of the slope. Only the lower parting could be separated by picking and therefore was not included in the sample. Analysis 9462 was made of a composite sample containing equal parts of all the samples taken from this mine. The analyses of these samples are given on pages 60–61.

Character and quality of the coal.—The coal in this mine is pitch black, massive, and slightly banded. In general it breaks with an irregular fracture, though a part of it has a tendency toward a splintery fracture. It has about the same heating value as coal obtained from the mines at Roslyn.

ROSLYN NO. 7.

Roslyn No. 7, a slope mine one-half mile northwest of Clealum, on a spur from the Northern Pacific Railway. No. 46.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal bed.—The mine is located on the Roslyn bed, which strikes about N. 65° W. and dips from 20 to 30° SW. The overlying sandstone is separated from the coal by about 3 feet of shale, of which the lower 2 to 6 inches breaks after the coal is removed, and is thrown into the gob. The remaining shale, however, forms a good roof throughout most of the mine, and the floor is firm and does not mix with the coal. The following sections were measured at the places where the samples were taken:

Sections of Roslyn coal bed in Roslyn No. 7 mine.

No. 9422.

	Ft.	in.
Shale.		
*Coal	1	2
Shale		½
*Coal, streaks of "sulphur"	1	6½
*Shale		½
*Coal		2
Shale		1
*Coal	1	6
Shale.		
	4	6½

No. 9420.

	Ft.	in.
Shale.		
Shale, soft		1½
*Coal, crushed		4
*Coal		10
Shale		1
*Coal, partly crushed	1	6½
Coal and shale streaks		2
*Coal		2
*Shale		½
*Coal	1	8½
Shale.		
	5	

No. 9421.

	Ft.	in.
Shale.		
*Coal	1	2
"Sulphur" band		½
*Coal	1	2½
Shale		1
*Coal		1½
"Sulphur" band		¼
†Coal		1
*Shale		½
*Coal		4
Shale		½
*Coal	1	6½
Shale.		
	4	8½

No. 9419.

	Ft.	in.
Shale.		
Shale, carbonaceous streaks		1
*Coal	2	½
Shale		1
*Coal		1½
*Shale		1
*Coal		4
*Coal, banded		2
*Coal	1	6½
Shale.		
	4	5½

Preparation for market.—Partings and impurities which separate readily from the coal are removed in the mine, and as all the coal is used for locomotives it needs no further picking at the tipple.

Samples for analysis.—Sample 9422 was taken on the gangway of the second level west, 6 feet up room 40. The upper and the lower partings of the bed can be separated by picking and were not included in the sample. Sample 9421 was taken on the gangway of the second level east, 15 feet from the barrier between mine No. 7 and mine No. 1 at Clealum. The bed contains five partings, most of which can be separated from the coal by careful picking. A parting of shale, "sulphur" and coal occurs near the center of the bed. In picking, about half the coal in this parting will be thrown away, and, accordingly, in sampling, only half the coal and the layer immediately underlying it was included in the sample. Sample 9420 was taken in the air course below the gangway of the fourth level west, about 800 feet west of the slope. The two upper partings in the bed, which can be separated by careful picking, were not included in the sample. Sample 9419 was taken on the gangway of the fourth level east, 330 feet beyond the entrance to room 12. The upper parting, which is the only one that can be separated from the coal by picking, was not included in the sample. Analysis 9461 was made of a composite sample containing equal parts of the samples taken at this mine. The analyses of the samples are given on page 61.

Character and quality of the coal.—The coal is grayish black, massive, and banded, and breaks with a splintery fracture. On account of the banding, it is difficult to distinguish some parts of the coal from bony layers containing a high percentage of carbon. The coal has a heating value a little lower than the coal obtained from this bed at the mines further to the northwest.

SUMMIT.

Summit, incline 1 mile north of Clealum. No. 47.

Operator: Summit Coal Mining Co., Portland, Oreg.

Kind of coal: Bituminous.

Coal bed.—The mine is on the Roslyn bed, which here strikes N. 75° W. and dips 11° S. The following section was measured at the point from which the sample was taken:

Section of Roslyn coal bed at Summit mine.

No. 9403.

	Ft.	in.
Sandstone.		
Shale (5 inches to 1 foot 6 inches)		11
Shale with streaks of coal		5
*Coal	2	5½
Shale		½
*Coal		2
Shale		½
*Coal	1	9½
Shale.		
	5	10

Preparation for market.—The partings and impurities that can be separated readily at the mine are thrown into the gob. At the tipple the coal is passed over two 2-inch bar screens, the oversize, after picking, being marketed as lump coal, and the undersize as steam coal.

Sample for analysis.—Sample 9403 was taken down the gangway 50 feet from the new tunnel about 40 feet below the surface. Both shale partings of the bed were excluded from the sample. The analysis of the sample is given on page 61.

Character and quality of the coal.—The coal is grayish black, massive, and slightly banded, and has a splintery fracture. Its heating value is somewhat lower than that of the coal obtained from the same bed farther to the west.

CLE ELUM NO. 3 EXTENSION.

Cle Elum No. 3 Extension, incline and drift mine about 1 mile north of Clealum. No. 48.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal bed.—The mine is worked on the Roslyn bed, which strikes N. 70° W. and dips about 9° S. The coal is separated from massive sandstone by about 3 feet of shale, fragments of which, the largest a foot in thickness, break off after the coal is mined and are thrown into the gob. Occasionally it breaks with the coal, in which event it must be separated before the mine cars are loaded. The floor is firm and does not mix with the coal. The following section was measured where the sample was obtained:

Section of Roslyn coal bed at Cle Elum No. 3 Extension mine.

No. 9408.

	Ft.	in.
Shale.		
Shale, carbonaceous, and bone	1	
*Coal	2	8½
Shale		½
*Coal		4
*Shale, hard		1
*Coal	1	2½
Shale.		
	5	4½

Preparation for market.—Partings and impurities which separate readily from the coal are removed in the mine, and as all the coal is used for locomotives it needs no further picking at the tipple.

Sample for analysis.—Sample 9408 was taken from the air course which parallels the incline, just below the sixth level, and does not include the upper parting of the bed. The analysis of the sample is given on page 61.

Character and quality of the coal.—The coal is grayish black, massive, and banded, and breaks with a splintery fracture. The bony layer in the bottom of the bed resembles the surrounding coal to such an extent that it was difficult to separate them and its presence does not seem to have materially increased the amount of ash in the sample. This coal has a heating value a little lower than that of coal obtained from the same bed in the vicinity of Roslyn.

CLE ELUM NO. 2 EXTENSION.

Cle Elum No. 2 Extension, incline and drift mine about 1 mile north of Clealum. No. 48.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal bed.—The mine is located on the Roslyn bed, which strikes N. 80° W. and dips 9° S. The coal is separated from massive sandstone by about 3 feet of shale, pieces of which ranging up to a foot in thickness break off after the coal is mined and are thrown into the gob. When they break with the coal, they must be separated from it before the mine cars are loaded. The floor is firm and does not mix with the coal. The section following was taken from the place where the sample was obtained.

Section of Roslyn coal bed in Cle Elum No. 2 Extension mine.

No. 9409.

	Ft.	in.
Shale.		
Shale, slightly carbonaceous		6
*Coal	1	2½
†Shale, hard		1
*Coal	1	3
*Shale, hard		¼
*Coal		1½
Shale		¾
Coal		1
Shale		½
*Coal		4
*Shale, hard		½
*Coal	1	5
Shale, hard.		
	5	2

Preparation for market.—Partings and impurities that separate readily from the coal are removed in the mine, and as all the coal is used for locomotives it needs no further picking at the tipple.

Sample for analysis.—Sample 9409 was taken on the gangway of the eighth level about 50 feet east from the rope slope. Half the upper parting and the entire bench near the center of the bed was excluded from the sample. The analysis of this sample is given on page 61.

Character and quality of the coal.—The coal is grayish black, massive, and banded, and has a splintery fracture. It has a lower heating value than coal obtained from the same bed farther northwest.

CLE ELUM NO. 2.

Cle Elum No. 2, one-half mile north of Clealum. No. 48.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal bed.—The mine is worked on the Roslyn bed, which strikes N. 55° W. and dips about 14° SW. The coal is separated from a massive sandstone by about 3 feet of shale, fragments of which ranging up to a foot in thickness break off after the coal is mined and are thrown into the gob. It occasionally breaks with the coal and must be separated before the mine cars are loaded. The floor is firm and does not mix with the coal. The following section was measured where the sample was obtained:

Section of Roslyn coal bed in Cle Elum No. 2 mine.

No. 9472.

	Ft.	in.
Shale.		
Shale, soft		8½
*Coal	1	1
"Sulphur" band and coal		1
*Coal		6½
*Coal, bony		½
*Coal		7
Shale and coal layers		3½
*Coal	1	5½
Shale.		
	4	9½

Preparation for market.—Partings and impurities which separate readily from the coal are removed in the mine, and as all the coal is used for locomotives it needs no further picking at the tipple.

Sample for analysis.—Sample 9472 was taken at the face of the gangway of the sixth level east. The upper and the lower partings of the bed can be separated by careful picking and were not included in the sample. The analysis of the sample is given on page 62.

Character and quality of the coal.—The coal is grayish black, massive, and banded, and has a splintery fracture. Bony layers in the coal resemble the coal so much that they can be separated only with great care.

CLE ELUM NO. 1.

Cle Elum No. 1, a shaft mine 250 feet deep at Clealum, on the Northern Pacific Railway. No. 48.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal bed.—This mine is on the Roslyn bed, which strikes N. 65° W. and dips 24° S. in the west end of the workings, and strikes N. 55° W. and dips 31° S. in the east end of the workings. The coal is separated from a massive sandstone by about 3 feet of shale, of which fragments ranging up to a foot in thickness break off after the coal is mined and are thrown into the gob. Occasionally it breaks with the coal and must be separated before the mine cars are loaded. The floor is firm and does not mix with the coal. The following sections were measured at the points from which the samples were obtained:

Sections of Roslyn coal bed in Cle Elum No. 1 mine.

No. 9445.

Shale.	Ft.	in.
Shale (gobbed)		9½
*Coal	2	
Shale		½
†Coal		1
Shale		½
†Coal		2
Shale		½
*Coal		5½
*Shale, hard		½
*Coal	1	4
*Shale, hard		½
*Coal		2
*Shale		½
*Coal		1
Shale.		
	5	3½

No. 9446.

Shale.	Ft.	in.
Shale (gobbed)		5
*Coal	1	½
Shale		½
*Coal	1	2½
*Shale		½
*Coal		3
Shale		1
*Coal		5½
Shale		1
*Coal	1	2½
Shale.		
	4	10

No. 9447.

Shale (poor roof).	Ft.	in.
Clay, soft		1
*Coal	2	5½
Shale, upper part hard		1
*Coal		6
*Shale		1
*Coal	1	
Shale	1	1
	5	3½

Preparation for market.—Partings and impurities which separate readily from the coal are removed in the mine, and as all the coal is used for locomotives it needs no further picking at the tipple.

Samples for analysis.—Sample 9445 was taken from the gangway on the first level southwest between rooms 32 and 33. Only about half of the coal between the three upper partings could be removed by careful picking, and therefore the partings, with the remaining half of the coal, were not included in the sample. Sample 9446 was taken from the gangway of the first level southwest, 100 feet from the slope. The upper and the two lower partings can be separated from the coal by picking, and were not included in the sample. Sample 9447 was taken at the east end of the gangway on the first level southeast. The upper parting can be separated by picking and was, therefore, not included in the sample. Analysis 9467 was made of a composite sample containing equal parts of the samples obtained from this mine. The analyses of these samples are given on page 62.

Character and quality of the coal.—The coal is grayish black, massive, and banded, and has a splintery fracture. The bed contains some partings of bony coal, which are banded and which can be separated only with difficulty from the coal. The heating value of the coal is lower than that of coal obtained from the mines on the same bed farther northwest.

LEWIS COUNTY.

The samples collected in Lewis County were obtained from three fields—the anthracite field on the headwaters of Cowlitz River, the bituminous field at Ladd, and the subbituminous field near Centralia and Chehalis. The geologic relations of these fields to one another has not yet been determined, except that the coal-bearing rocks in all three fields belong to the Puget formation of the Tertiary system.[1] The samples upon which this report is based were collected during August and September, 1909, and February, 1910. Several samples obtained during 1908 by J. B. Umpleby, of the United States Geological Survey, at Ladd and in the vicinity of Glenavon have also been included in this report.

Gas is said to occur in the Primrose bed along Summit Creek, in the anthracite district, and has been seen by the writer bubbling from some of the coal beds in the bottom of the creek. In the mine at Ladd the beds have been cut by igneous rocks in several places, and gas is especially abundant where these intrusions occur. In bed No. 2 gas is found in small quantities throughout the entire workings.

PROSPECT NORTH OF CARLTON CREEK.

Prospect on the north side of valley, about 500 feet vertically above Carlton Creek, in SE. ¼ NW. ¼ sec. 29, T. 15 N., R. 11 E. No. 49.

Kind of coal: Carbonaceous shale.

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[1] Willis, Bailey, Tacoma folio (No. 54), Geol. Atlas U. S., U. S. Geol. Survey, 1899.

Coal bed.—This coal bed occurs in the lower coal group of the Carlton Pass coal field. An open cut has been made across the face of the bed, exposing a total thickness between hanging and foot walls of about 9 feet. The bed is composed almost entirely of black shale containing very thin stringers of bright coal and several layers of very badly crushed graphitic shale. The following is a section of the bed:

Section of coal (?) bed in SE. ¼ NW. ¼ sec. 29, T. 15 N., R. 11 E.

No 9093.

	Ft.	in.
Shale, sandy, carbonaceous.		
*Shale, graphitic	1	6
Shale, hard, black		7
Shale, graphitic		3½
Shale, black, thin stringers of pure coal	2	
Shale, black, hard		8½
Shale, graphitic	1	7
Shale, carbonaceous, with thin stringers of bright coal	1	11
Sandstone and shale, with thin layers of carbonaceous shale.		
	8	7

Sample for analysis.—Sample 9093 was taken from the graphitic shale layer 1 foot 6 inches thick near the top of the bed.

Character and quality of the coal.—The material is badly broken and shows considerable movement in the bed. When wet, the slickensided faces are very bright and give the appearance of anthracite coal. This bench was thought by the writer to contain a high percentage of graphite, and has been considered generally by coal prospectors who visited this field to be a high-grade coal. The analysis in the accompanying table (p. 62) shows that the bench is hardly better than carbonaceous shale.

PROSPECT SOUTH OF CARLTON CREEK.

Prospect on hillside south of Carlton Creek in SE. ¼ sec. 1, T. 14 N., R. 10 E., about 1,100 feet above the bed of the creek. No. 50.

Kind of coal: Semibituminous.

Coal bed.—A gangway 90 feet in length has been driven on this bed which strikes north and south and dips 60° W. At the end of the gangway the following section was measured:

Section of coal bed in prospect in SE. ¼ sec. 1, T. 14 N., R. 10 E.

No. 9091.

	Ft.	in.
Shale.		
Shale, black	3	2½
Coal, partly graphitic		7
Shale, black, carbonaceous	1	
*Coal	3	6
Coal, impure	1	6
Sandstone.		
	9	9½

Sample for analysis.—Sample 9091 was taken from the bed of good coal 3 feet 6 inches thick, and its analysis is given in the table (p. 62).

Character and quality of the coal.—The coal is very hard and bright, but contains a few thin stringers of dull coal. It burns on a forge with a short blue flame and has the appearance of anthracite coal. Analysis shows that it is very high in ash. It is massive and banded, and breaks with a conchoidal fracture.

PROSPECT A, SUMMIT CREEK.

Prospect on Summit Creek in SE. ¼ NW. ¼ sec. 13, T. 14 N., R. 10 E. No. 51.

Kind of coal: Semibituminous and semianthracite.

Coal bed.—This bed, which is known as the Primrose bed, is about 20 feet in thickness between hanging and foot walls. A gangway has been driven about 50 feet in the lower part of the bed, which is slightly overturned, dipping 82° and striking north and south. The following section shows the details of the bed:

Section of Primrose coal bed in prospect in SE. ¼ NW. ¼ sec. 13, T. 14 N., R. 10 E.

	Ft.	in.
Shale, hanging wall.		
*(1) Coal, with thin layers of bone (sample 9101)	2	8½
(2) Coal, bony, with some graphitic shale	2	6
*(3) Shale, graphitic (sample 9097)	1	5
(4) Shale, black		8½
*(5) Coal and layers of bony coal (sample 9102)	2	1
*(6) Coal (sample 9099)	4	11
(7) Coal and graphitic shale in alternating layers	3	11
(8) Shale, black	2	
Sandstone, footwall.		
	20	3

Samples for analysis.—The section was measured and the samples taken from the face of an open cut across the bed at the entrance to the gangway. Bench No. 1, from which sample 9101 was taken, contains a large percentage of hard, bright coal resembling that from bench No. 6, but the numerous thin layers of bony coal scattered through the bed can be separated from pure coal only with extreme difficulty, and will increase the percentage of ash in the bed very considerably. No sample of bench No. 2 was taken, but the coal resembles that sampled in bench No. 5. Sample 9097, taken from the graphitic shale of bench No. 3, shows on analysis that this bench is too high in ash to be of economic value. Sample 9102, taken from bench No. 5, contains a large amount of ash, and is too impure to be of commercial value at the present time. Sample 9099 was taken from bench No. 6, and represents the best coal in the bed. Sample 9100 was obtained from a layer of the best coal near the center of bench No. 6, and represents the best picked coal from the bed. The analyses of these samples are given on page 63.

Character and quality of the coal.—The coal from bench No. 6 is pitch black, bright, and very hard. It is massive and breaks with an irregular conchoidal fracture. In the other benches the coal is not so pure, is banded and laminated, and breaks with an irregular, splintery fracture. The coal burns in an open fire with a short blue flame and, in general, leaves a fairly large amount of ash, though a sample taken from the best layer in the center of bench No. 6 has a fuel ratio of 11 and a relatively small percentage of ash. The analysis (No. 9100) of this sample compares favorably with the analyses of some of the anthracite coals of Pennsylvania. The percentage of volatile matter is somewhat higher than in the average Pennsylvania anthracite, but lower than that of the semianthracite coal of Sullivan County, Pa., which is sold in the market as anthracite.

PROSPECT B, SUMMIT CREEK.

Prospect on Summit Creek, in SE. ¼ NW. ¼ sec. 13, T. 14 N., R. 10 E. No. 51.

Kind of coal: Semianthracite.

Coal bed.—The bed is slightly overturned at this place, and has the same dip and strike as that given for the Primrose bed in the preceding description. It is separated from the Primrose by 25 feet of shale. The following section was measured at the face of a drift run along this bed 35 feet:

Section of coal bed in prospect in SE. ¼ NW. ¼ sec. 13, T. 14 N., R. 10 E.

No. 9098.

	Ft.	in.
Shale.		
*Coal	2	9½
Coal, poor		7
Shale, black	3	
Coal, bony	2	2½
Shale.		
	8	7

Sample for analysis.—Sample 9098 was taken from the best bench of coal in the section noted above. The coal was more or less crushed and mixed with carbonaceous shale. The analysis of this sample is given on page 63.

Character and quality of the coal.—The coal is pitch black, bright, and hard. It is massive and dense, and breaks with a conchoidal fracture. Analysis shows that the coal contains a very high percentage of ash, and although it is classed as a good grade of semianthracite, the percentage of ash in the entire bed is so high that it would be of little value commercially unless the carbonaceous shale could be separated thoroughly by crushing and washing.

PROSPECT C, SUMMIT CREEK.

Prospect on Summit Creek, in SE. ¼ NW. ¼ sec. 13, T. 14 N., R. 10 E., about 350 feet west of the opening on the Primrose bed previously described. No. 51.

Kind of coal: Anthracite.

Coal bed.—The coal bed, which belongs to the same group as the Primrose bed, outcrops very near the level of the creek, and only the middle of it was exposed in the prospect. It is slightly overturned, and has a dip and strike practically the same as that of the Primrose. The following section was measured:

Section of coal bed in prospect in SE. ¼ NW. ¼ sec. 13, T. 14 N., R. 10 E.

No. 9092.

	Feet.
Coal, bony	1+
*Coal	1
Coal, bony	1+
	3+

Sample for analysis.—Sample 9092 was taken from the 1-foot bench of good coal. The analysis is given on page 63.

Character and quality of the coal.—The coal, which is very bright, pitch black, and hard, is massive and dense, and breaks with a conchoidal fracture. It contains a low percentage of ash and has a high calorific value. The coal is an anthracite and compares favorably with much of the Pennsylvania anthracite.

SURFACE EXPOSURE EAST OF COWLITZ RIVER.

Surface exposure in SE. ¼ sec. 7, T. 13 N., R. 10 E., about 2 miles east of Cowlitz River. No. 52.

Kind of coal: Anthracite.

Coal bed.—The coal bed outcropping near the summit of the hill strikes N. 5° E. and dips 32° W. The bed has a total thickness of about 18 feet, only 3 feet of which was thought to be pure enough to be of any commercial value. The remainder of the bed is composed almost entirely of a hard black shale containing thin stringers of coal.

A drift was run about 20 years ago on a bed outcropping on the opposite side of the hill, about 200 feet below the outcrop described above, and it has always been supposed that the drift and the surface exposure are on the same bed. It was reported that a sample taken from the drift and analyzed at the New Orleans exposition showed 92 per cent of fixed carbon. It is very clear from the analysis and physical character of the coal from the surface exposure that the drift must be on a different bed.

Sample for analysis.—Sample 9090 was taken from the 3-foot bench of bony coal after removing about 6 inches of coal from the face of the exposure. The analysis of the coal is given on page 63.

Character and quality of the coal.—The small stringers of coal, which are very hard and jet black, and break with a conchoidal fracture, should probably be considered as anthracite. It would be impossible to separate them from the bony coal in which they are embedded, and the marketable coal would have about the same percentage of ash as that contained in this sample.

PROSPECTS NEAR LADD AND GLENAVON.

Prospects in the vicinity of Ladd and Glenavon, Washington. Nos. 82, 83, 84, 85, 86, and 87.

Kind of coal: Bituminous and anthracite.

Coal beds.—On account of the heavy forest covering, the exposures are very small and the relation of the beds in each part of the field can not be definitely worked out from the surface. J. B. Umpleby examined this area in 1908 and measured the following sections, from which he obtained the samples.

Sections of coal beds in the vicinity of Ladd and Glenavon.

No. 6488.

Hanging wall.	Ft.	In.
Coal, shaly	1	1
Parting		4½
*Coal		11
Parting		2
*Coal		5
Parting		1
*Coal	1	7
Parting		1½
*Coal	1	1
Coal, slaty		9
Clay, plastic.		
Footwall.		
	6	7

No. 6490.

Clay, hanging wall.	Ft.	In.
*Coal	1	6
Volcanic ash		1
*Coal		8½
Parting		9½
*Coal	1	
Parting		1
*Coal		3½
Parting		1
*Coal	1	
Parting		1
*Coal	1	6
Shale, footwall.		
	7	1½

No. 6489.

Hanging wall.	Ft.	In.
Coal, very bony	1	4
Clay, sandy		5
Coal, very bony		11
Clay		½
Coal and bone in alternating bands		10
Clay		½
*Coal, bony, dull layers		4½
Clay		4½
*Coal, hard, dull layers		8
Clay		1
*Coal, bony		8
Footwall.		
	5	9

No. 6495.

Clay, hanging wall.	Ft.	In.
*Coal	3	6
Parting		5½
*Coal	1	7
Parting		3
*Coal		8
Clay, footwall.		
	6	5½

No. 6496.

Clay, hanging wall.	Ft.	In.
*Coal	1	1
Parting	1	11
*Coal	2	5
Parting	1	
Coal, bony		2½
Clay.		
Shale and coal, bony, footwall.		
	6	7½

Samples for analysis.—Sample 6488 was taken from a drift 60 feet long in the SE. ¼ sec. 14, T. 13 N., R. 4 E. All the partings were removed in sampling. Sample 6489 was taken from a 33-foot drift in the northeast corner of the SW. ¼ NE. ¼ sec. 26, T. 14 N., R 4 E. Sample 6490 was taken from an open cut 10 feet deep in the NE. ¼ sec. 10, T. 13 N., R. 4 E., all partings being excluded. Sample 6495 was taken from an open cut near some small faults in the SE. ¼ sec. 34, T. 14 N., R. 4 E. It is not certain that the bed is normal at this point. Both partings were excluded from the sample. Sample 6496 was obtained from a 26-foot drift in the NW. ¼ sec. 14, T. 13 N., R. 4 E. The part sampled contained one parting which was excluded from the sample. The analyses of these samples are given on pages 63–64.

Character and quality of the coal.—The physical character of the coal is not known to the writer. Analyses show moderate to very high amount of ash; the amount of moisture given off is somewhat high, due probably to moisture on the surface of the coal, which was not removed before the samples were sealed. The coal does not slack on exposure to the air. The percentage of fixed carbon is considerably higher than that of volatile matter, in which respect the coals compare with that from mine No. 1 at Ravensdale. Sample 6496 shows a remarkably small amount of volatile matter, and the analysis indicates either that the coal is anthracite or natural coke. With this exception, the samples indicate that this is an impure bituminous coal.

EAST CREEK-LADD.

East Creek-Ladd, a tunnel and drift mine at Ladd, on the Tacoma Eastern Railroad. No. 53.

Operator: East Creek Coal Co.; W. M. Ladd and J. Bagley, Ladd, Wash.

Kind of coal: Bituminous (coking and noncoking).

Coal beds.—Two coal beds, Nos. 2 and 3, were being developed commercially at the time of sampling and a third bed, lying above Nos. 2 and 3 and called No. 4, was being prospected. The beds strike N. 85° W. and dip 40° SW. Bed No. 2, the main commercial bed and the lowest in the group, is being worked on the property of the East Creek Coal Co., and coal is brought to the surface by a gangway and a rock tunnel through the property of W. M. Ladd and J. Bagley. Bed No. 3 lies 590 feet west of bed No. 2 and is being developed in the valley of a small creek southwest of the main entrance to No. 2. A gangway 250 feet long has been driven on this bed. A short gangway has been driven on bed No. 4, which is 160 feet west of bed No. 3, near the entrance to the gangway on No. 3. Sections of these coal beds at the places where the samples were taken are as follows:

Sections of coal beds in East Creek-Ladd mine.

No. 9882, bed No. 2.

	Ft.	in.
Sandstone.		
Shale { 6 to 2	2	6
Shale, carbonaceous, soft		7
*Coal		10
Shale, clayey		1
*Coal, "sulphur" in joints	1	9
Shale, carbonaceous		4
*Coal, calcite veins		11
Coal bed	3	11

No. 9880, lower bench of bed No. 3.

	Ft.	in.
Coal.		
Shale and bony coal		6½
*Coal	3	6½
Coal, bony.		
	4	1

No. 9881, upper bench of bed No. 3.

	Ft.	in.
Shale.		
*Coal	1	8
Shale and bony coal		6½
	2	2½

No. 9879, bed No. 4.

	Ft.	in.
Coal, bony, and shale	2	8½
*Coal	1	8
Shale		1
*Coal	1	
Shale		3
Coal, bony		2½
Shale		½
*Coal	1	
*Shale		½
*Coal		5
Shale.		
Shale, and coal, bony.		
	7	5

The following sections were measured in this mine by J. B. Umpleby in 1908:

Sections of coal beds in East Creek-Ladd mine.

No. 6493, bed No. 2.

	Ft.	in.
Clay.		
*Coal		9½
Parting		1
*Coal	1	11
Parting		1
*Coal	1	5
Clay.		
	4	3½

No. 6493, bed No. 4.

	Ft.	in.
Coal, bony	16	6
*Coal	1	11
Bone		2½
*Coal	2	3½
Shale.		
	20	11

No. 6494, bed No. 3.

	Ft.	in.
Coal	1	6
Parting		1
Coal		8½
Bone		3½
*Coal	4	1
Parting		11
Coal	1	8½
Shale.		
	9	3½

Preparation for market.—The coal from bed No. 2 is picked at the bunker and washed through a Howe tub washer. The coal from No. 3 is picked at the entrance of the gangway and then flumed to the washer at the entrance to bed No. 2, where it is mixed with the coal from No. 2 and passed through the washer.

Samples for analysis.—A sample (No. 9882) of bed No. 2 was taken 60 feet up chute 62 from the first water-level gangway. The two shale partings given in the section can be separated from the bed by careful picking and washing, and were not included in the sample. Two samples were taken at the face of the gangway on bed No. 3—No. 9881 from the upper bench and No. 9880 from the lower bench. These benches are separated by 6½ inches of shale and bony coal which is removed from the coal by picking. Sample 9879 was obtained from the face of the gangway on bed No. 4. The bed contains several partings of shale and bony coal. It will probably be somewhat difficult to separate the bony coal from the commercial parts of the bed, but inasmuch as the lower shale parting in the bed was not removed in the sampling it was thought that by removing all the bony coal the resulting amount of ash in the sample would represent that obtained in the ordinary commercial coal from this bed. Sample 6493 was taken from bed No. 2, the two partings of which were not included in the sample. None of the partings were included in sample 6494, taken from bed No. 3. Sample 6492 was taken from the short drift on bed No. 4 where No. 9879 was taken. The parting was not included in the sample. Sample 6491, consisting of two samples of about 300 pounds each of washed coal from bed No. 2, was taken at the bunker as it came from the washer. Each sample was reduced and quartered in the usual manner until 100 pounds were obtained. The two samples were then mixed, ground, and quartered until the final sample was about 4 pounds. It was sealed in the can while still wet.

Analyses of the samples will be found on pages 64–65.

Character and quality of the coal.—The coal from bed No. 2 is bright, has a cubical fracture, and is of better quality than that from either bed No. 3 or No. 4. It is rather high in ash and produces coke of fairly good quality. The joints in the coal are very close together, and are, in the lower portion of the bed, filled with calcite, pyrite, and free sulphur. The coal from bed No. 3 is banded and is heavier than that from bed No. 2, but not nearly so bright or well jointed. Both benches of this bed contain coal of similar quality. The coal, though high in ash, is considered fairly good for railroad and domestic use. The coal from bed No. 4 resembles very much the coal from bed No. 3, but it is higher in ash and therefore lower in heating value. The coal from all three beds contains a small percentage of moisture, does not slack during transportation to the market, and may be classed as bituminous.

MENDOTA.

Mendota, a slope mine at Mendota, about 6 miles east of Centralia on the Centralia Eastern Railroad. No. 54.

Operator: Mendota Coal & Coke Co., Centralia, Wash.

Kind of coal: Subbituminous.

Coal bed.—Several coal beds are exposed on the property of the company, but only the one upon which the mine was working was sampled. The bed strikes north and south and dips 12° W. The following sections were measured at the places at which the samples were taken:

Sections of coal bed in Mendota mine.

No. 10324.

	Ft.	in.
*Coal	2	2½
Shale, sandy		2½
*Coal	1	1
Shale, sandy		½
*Coal	2	
Shale, yellow-brown		1
*Coal		2½
Shale		½
*Coal, little stringers of bone		9½
Shale, yellow-brown		½
*Coal	3	
	9	8½

No. 10323.

	Ft.	in.
*Coal	1	4
†Shale, sandy		½
*Coal		6½
†Shale, sandy		½
*Coal	3	6
Shale		1
*Coal		3
Shale		½
*Coal	4	2½
	10	½

Preparation for market.—When the partings are large and separate easily from the coal they are removed in the mine. The coal is picked and sized at the tipple over a shaking screen with 2-inch perforations.

Samples for analysis.—Sample 10324 was collected 80 feet above the gangway at the first level north in room No. 2. At this place all of the partings in the bed can be separated by careful picking, and hence they were not included in the sample. Sample 10323 was taken at the foot of the slope, 850 feet from the entrance of the mine. The bed contains four partings. It would be difficult to separate all the material in upper two partings from the coal, and therefore about one-half of each was included in the sample. The analyses of these samples are given on page 65.

Character and quality of the coal.—The coal is grayish black and has a reddish-brown streak. It is massive and banded, and breaks with a conchoidal fracture. It slacks readily upon exposure to the air, owing to the large amount of moisture it contains—an amount about equal to that of the coal from the Hannaford mine. It has, however, less fixed carbon than this coal, a greater amount of ash and sulphur, and a lower heating value. It has considerably less moisture than the coal in the vicinity of Chehalis and will probably stand transportation better. It should be classed as low-grade subbituminous.

Irregular lenses of a soft cannel-like coal occur in places in this mine. When first exposed these lenses are black and give a yellowish brown streak, but they turn brown very soon. The percentage of volatile matter in them is very high, for large pieces can be easily ignited in the hand with a match, and they burn much more readily than any cannel with which the writer is familiar, with a long, smoky, yellow flame.

RICHMOND.

Richmond, a slope mine 1½ miles northeast of Centralia. No. 55.

Operator: Centralia Coal Co., Centralia, Wash.

Kind of coal: Subbituminous.

Coal bed.—Only one coal bed is developed at this mine. It strikes N. 40° W. and dips 40° SW. The following section was measured at the face of the north gangway, just beyond chute No. 10 on the first level:

Section of coal bed in Richmond mine.

No. 9177.

	Ft.	in.
Coal	1	
Shale, hard		6
Coal (used as roof)		8½
*Coal	7	8½
Coal and shale, carbonaceous		6
Coal	1+	
	11	5+

Preparation for market.—The coal is passed over a ¾-inch screen and then picked. Only the lump coal is placed on the market.

Sample for analysis.—Sample 9177 was cut at the place where the above section was measured. The analysis of the coal is given on page 65.

Character and quality of the coal.—The coal is brownish black in color, and has a reddish-brown streak. It is massive and banded, and breaks with an irregular conchoidal fracture. It contains a very high percentage of moisture and weathers very readily on exposure to the air. It should be classed as a very low-grade subbituminous coal.

SUPERIOR NO. 1.

Superior No. 1, a water-level mine 1 mile northeast of Chehalis. No. 56.

Operator: Superior Coal Co., Chehalis, Wash.

Kind of coal: Subbituminous.

Coal bed.—This coal bed is about 11 feet in thickness. It strikes N. 70° W. and dips 40° SW. The entire bed of coal, which is the same bed as that mined in the Twin City mine of the Twin City Light & Traction Co. about one-fourth mile west, is mined, but as the sample from the Twin City mine was taken from the lower bench very near this mine it was considered that a sample from the upper bench to supplement the Twin City mine sample was all that was necessary. The following is a section of the upper portion of the bed at this mine and that from which the sample was taken:

Section of upper part of coal bed in Superior No. 1 mine.

No. 9942.

	Ft.	in.
Sandstone.		
*Coal	1	7
Shale, sandy		½
*Coal		3
Shale, sandy		½
*Coal	2	
Shale		1
*Coal		6
Shale, hard.		
Shale.	4	6

Preparation for market.—The coal is passed over a 1-inch bar screen at the bunker, picked, and dumped into the bin.

Sample for analysis.—Sample 9942 was taken 10 feet east of the entrance to the tunnel to the bed. The analysis of the coal is given on page 65.

Character and quality of the coal.—The coal is brownish black and has a reddish-brown streak. It is massive and banded and breaks with an irregular conchoidal fracture. Owing to its high percentage of moisture, it slacks very readily upon exposure to the air. It is probably on the border line between low-grade subbituminous and high-grade lignite.

SUPERIOR NO. 2.

Superior No. 2, a slope mine one-fourth mile north of the station at Chehalis, on the main line of the Northern Pacific Railway. No. 57.

Operator: Superior Coal Co., Chehalis, Wash.

Kind of coal: Subbituminous.

Coal bed.—The coal bed is nearly 10 feet in thickness. It strikes N. 80° W. and dips 54° S. The following section was measured where the sample was taken:

Section of coal bed in Superior No. 2 mine.

No. 9941.

	Ft.	in.
Sandstone, soft.		
*Coal	3	11
*Coal	4	6
*Coal, slightly bony and soft		5½
Shale, carbonaceous, soft		1
*Coal		9
Coal, bony		2
Sandstone.		
	9	10½

Preparation for market.—The coal is passed over a 1-inch bar screen at the bunkers and then picked.

Sample for analysis.—Sample 9941 was obtained in chute 5 about 50 feet above the first level gangway. The bed contains one carbonaceous shale parting near the bottom, which can be separated by picking, and was not therefore included in the sample. The analysis of the coal is given on page 65.

Character and quality of the coal.—The coal has a brownish-black color, a reddish-brown streak, massive and banded structure, and a conchoidal fracture. It contains a high percentage of moisture, slacks very easily upon exposure to the air, and is a very low-grade subbituminous coal.

TWIN CITY.

Twin City, a slope mine 1 mile northeast of Chehalis. No. 58.
Operator: Twin City Light & Traction Co., Chehalis, Wash.
Kind of coal: Subbituminous.

Coal bed.—The coal bed worked in this mine is the lower part of the bed worked at the Superior No. 1 mine about one-fourth mile east. (See p. —.) It strikes No. 70° W. and dips 40° SW. The following section was measured where the sample was taken:

Section of lower part of coal bed in Twin City mine.

No. 9945.

	Ft.	In.
Shale.		
Coal, with thin irregular bands of shale	4	
Shale		6
* Coal	1	7
Shale		3½
* Coal	2	6
Shale		1
* Coal		7
* Shale, thin lens		½
* Coal		3½
Shale		½
* Coal		9½
Shale.		
	10	8½

Preparation for market.—The coal is passed over a bar screen and picked.

Sample for analysis.—Sample 9945 was taken at the east end of the first level gangway about 300 feet from the slope. The bed contains several shale partings which can be easily separated by picking and washing, and these were therefore not included in the sample. The analysis of the coal is given on page 65.

Character and quality of the coal.—The coal is brownish black and gives a reddish-brown streak. It is massive and banded, and breaks with an irregular conchoidal fracture. Its percentage of moisture is high and it slacks very readily upon exposure to the air. It is probably on the border line between low-grade subbituminous and high-grade lignite.

CHEHALIS.

Chehalis, a drift mine 2 miles east of Chehalis. No. 59.

Operator: Chehalis Coal Co., Chehalis, Wash.

Kind of coal: Subbituminous.

Coal bed.—The coal bed strikes N. 30° E. and dips 30° SE. The following section was measured at the place where the sample was obtained:

Section of coal bed in Chehalis mine.

No. 9944.

	Ft.	in.
Shale.		
* Coal	2	10
Shale, soft "mining"		9½
* Coal	2	9½
Shale.		
	6	5

Preparation for market.—The coal is screened and picked at the bunker.

Sample for analysis.—Sample 9944 was obtained in the first water-level gangway 250 feet from the entrance of the mine from a stump pillar which was then being drawn and which had probably been exposed in the mine air for some time. A parting of soft shale near the center of the bed is used as "mining" and is separated from the coal by picking. The analysis is given on page 66.

Character and quality of the coal.—The coal is brownish black and has a reddish-brown streak. It is massive and banded, and breaks with an irregular conchoidal fracture. It contains a high percentage of moisture and slacks very readily on exposure to the air. This coal is on the border line between low-grade subbituminous and high-grade lignite.

SHELDON.

Sheldon, a slope mine 3 miles east of Chehalis, Wash. No. 60.

Operator: Sheldon Coal Co., Chehalis, Wash.

Kind of coal: Subbituminous.

Coal bed.—The coal bed worked at this slope is about 6 feet thick. The section measured is as follows:

Section of coal bed in Sheldon mine.

No. 9943.

	Ft.	in.
Coal	2+	
* Coal	2	
Shale, carbonaceous		2½
Coal		6
Shale, carbonaceous		2
* Coal	3	5½
Shale.		

Preparation for market.—The coal is screened over a 1-inch bar screen and then picked.

Sample for analysis.—Sample 9943 was taken 250 feet east of the slope and 40 feet up the rise from the first level. The bed contains near the middle a parting of 10½ inches of carbonaceous shale and coal, which can be separated from the remainder of the bed by careful picking and washing, and this portion of the bed was not included in the sample. The analysis is given on page 66.

Character and quality of the coal.—The coal is brownish black and has a reddish-brown streak. The structure is massive and banded, and the fracture conchoidal. The high percentage of moisture causes the coal to slack very readily upon exposure to the air. The coal should be classed as low-grade subbituminous.

CRESCENT.

Crescent, a water-level mine 4 miles northwest of Littell, on logging road. No. 61.

Operator: Union Coal Co., Seattle, Wash.

Kind of coal: Subbituminous.

Coal bed.—Several coal beds have been opened at this mine, but a sample could be obtained only from the main bed. This bed strikes N. 85° W. and dips 40° S. A bench of coal 1 foot 6 inches thick is left as a roof to support the sand overlying it. Wherever this roof is broken and the rocks are moist the sand flows into the mine in large quantities and makes the conditions of operating very unsafe. This mine was not being operated at the time it was visited. The following section was measured at chute 17, between chutes 18 and 19, and about 800 feet from the entrance to the first water-level gangway.

Section of coal bed in Crescent mine.

No. 9940.

	Ft.	In.
Sand.		
Coal	1	6
*Coal		9½
Shale, hard		4
*Coal	1	6
*Shale		1
*Coal		3½
Shale, hard		6
Shale, yellow	1	
Shale, carbonaceous		9½
*Coal	1	5
Shale		½
*Coal	1	3½
Shale, carbonaceous.		
	9	6½

Sample for analysis.—Sample 9940 was taken where the section given above was measured. The bench of shale 2 feet 3½ inches thick near the center and small partings of shale in both the upper and lower benches of the bed should be removed in preparation for the market, and these were not included in the sample. The large amount of foreign material included in the bed, together with that which mixes with the coal from the floor and the roof, will increase the amount of ash in the marketable coal above that shown in the analysis very greatly unless it is very carefully removed. The analysis of the sample is given on page 66.

Character and quality of the coal.—The coal is brownish black in color, and has a reddish-brown streak. It is massive and banded, and breaks with a conchoidal fracture. It contains a higher percentage of moisture than any other coal sampled in the State, and slacks very readily on exposure to the air. This coal should be classed as subbituminous.

PIERCE COUNTY.

The coal fields of Pierce County have been studied by Bailey Willis and George Otis Smith.[1] The beds of the north end of the field were correlated by them on the data available in 1899, and the extension of the mines since then has essentially borne out their conclusions. The field has been developed to some extent farther south, at Melmont and Fairfax, but the relation of the beds worked in these places to those in the other mines farther north have not been definitely established.

The work of sampling was done in this county during December, 1909, and January, 1910. Two samples were taken from the Carbon Hill mine by M. R. Campbell in 1905, and a mine sample and a car sample were taken from the same mine by K. M. Way in 1908. A sample was taken in 1908 by J. B. Umpleby from a prospect about 7 miles east of Ashford. Descriptions of these samples and their analyses are here given for purposes of comparison.

Gas is present in considerable quantities in some of the mines. At Burnett and Carbonado safety lamps are used in many of the workings. At the south end of the levels from slope No. 1 on the Wingate bed at Carbonado so much gas is encountered along a well-defined zone which cuts diagonally across the workings that operations must be discontinued when this zone is reached.

[1] Willis, Bailey, Report on the coal fields of Washington Territory: Mining industries, Tenth Census U. S., vol. 15, 1886, pp. 759–771.

Willis, Bailey, Some coal fields in Puget Sound (Wash.): Eighteenth Ann. Rept., U. S. Geol. Survey, pt. 3, 1898, pp. 399–436.

Willis, Bailey, and Smith, G. O., Tacoma folio (No. 54), Geol. Atlas U. S., U. S. Geol. Survey, 1899.

BURNETT.

Burnett, a slope mine at Burnett, on the Northern Pacific Railway. No. 62.

Operator: Pacific Coast Coal Co., Seattle, Wash.

Kind of coal: Bituminous (coking).

Coal beds.—Two coal beds are being worked in the mine—bed No. 2, which is believed to be the same as the Wingate bed at Carbonado, and another believed to be bed No. 3 of the old workings and referred to by that number in this report. The southern end of this bed in the second water level is bounded by a fault and its relation to the other beds is not definitely known. The beds strike about N. 20° W. and dip 45° NE. Bed No. 2 varies somewhat in thickness in different parts of the mine. Bed No. 3 holds a fairly constant thickness, but the partings vary. The following sections were measured where the samples were taken:

Sections of coal beds in Burnett mine.

No. 9891, bed No. 2.

	Ft.	in.
Shale.		
Shale, carbonaceous		4½
*Coal	2	2½
Shale, soft, carbonaceous		5½
*Coal	1	6½
Shale, carbonaceous		8½
Shale, hard	6+	
Coal bed	4	2½

No. 9889, upper bench of bed No. 3.

	Ft.	in.
Shale, carbonaceous, poor roof.		
*Coal	1	6
Shale		5
Coal with irregular lenses of shale	5	7
Shale.		
	7	6

No. 9890, bed No. 3.

	Ft.	in.
Shale		5½
*Coal	1	4
Shale		5½
Shale, carbonaceous		2
*Coal	1	3
Shale		8
*Coal		½
Shale		4
*Coal		½
Shale		½
*Coal		4
Shale		1
*Coal.		
Coal bed	4	9

No. 9888, lower bench of bed No. 3.

	Ft.	in.
Shale, carbonaceous, poor roof.		
Coal	1	6
Shale		5
*Coal, with irregular lenses of shale	5	7
Shale.		
	7	6

Preparation for market.—No attempt is made to separate the impurities from the coal in the mine, but at the bunker (Pl. VII, *B*, p. 84) the coal is passed over a shaking screen having 1½-inch perforations, after which the oversize is picked on a link-belt picking table by six men and repicked over a 1½-inch bar screen before being

A. VIEW OF THE TOWN OF CARBONADO, PIERCE COUNTY.

B. NEW BEEHIVE COKE OVENS OF THE CARBON HILL COAL CO., AT CARBONADO, PIERCE COUNTY.

dumped into the bin. The undersize is washed in a Howe-Robinson tub washer.

Samples for analysis.—All the samples taken from the mine were obtained from the second level. Sample 9891 was taken from bed No. 2 on the first crosscut 2,200 feet south of the rock tunnel to bed No. 3. The bed contains a layer of soft carbonaceous shale which can be separated by careful picking and washing and was not included in the sample. The bed is overlain by 5 inches of carbonaceous shale which breaks with the coal and must be removed at the bunker. Sample 9890 was taken 15 feet above the gangway on bed No. 3 from the first manway south of the rock tunnel from bed No. 2. The bed contains six layers of shale, which can be separated from the coal by careful picking and washing and which were not included in the sample. It is overlain by about 6 inches of shale, more or less crushed, which mixes with the coal in mining and must be removed at the bunker. The lower part of the bed as exposed in this manway was still in the coal. Sample 9898 was taken from the north end of the gangway on bed No. 3 at a point 1,650 feet north of the rock tunnel from bed No. 2. The sample was taken on the upper bench of coal, which, together with the 5 inches of shale underlying it, is frequently left as a roof for the lower bench. This bench is overlain by badly broken carbonaceous shale, which makes a very poor roof, for it mixes with the coal and must be removed at the bunker. Sample 9888 was taken from the place where sample 9889 was obtained but from the lower bench. The bed contains irregular lenses of shale, most of which can be removed by careful picking and washing, and only a few of the thinnest were included in the sample. The shale underlying the bed is fairly firm and does not mix with the coal to any great extent.

Sample 9887 was taken from the surface of storage bins in the bunkers by selecting about 75 pounds of small lumps at random over the surface of the coal. The coal of this sample was reduced to about ½-inch mesh and then quartered. Opposite quarters were discarded and the remaining coal mixed and ground to the size of a pea. It was then quartered and reduced in the usual way until the final sample, about 4 pounds, was obtained. Sample 9886, which was taken from the surface of the bins and from a loaded 50-ton railroad car, consisted of wet coal direct from the washer; it was prepared for analysis in the same way as sample 9887, but was sealed in the can while still moist. The analyses of these samples are given on pages 66–67.

Character and quality of the coal.—The coal from bed No. 2 is pitch black, gives a dark-brown streak, and has a vitreous luster. It is massive and slightly banded, and breaks with an irregular, slightly conchoidal fracture resembling that of the Wingate coal at Carbonado and the McKay coal at Black Diamond. The coal contains a small amount of moisture and does not slack when exposed to the sun. Its heating value is nearly as high as that of any coal obtained in the State, and it should be classed as a high-grade bituminous coal. The coal from bed No. 3 is pitch black, and has a dark-brown streak and a vitreous luster. It is massive and laminated, and breaks with an irregular splintery fracture. The amount of moisture present in it is small, and it does not weather on exposure to the sun, but its ash content is greater than that of the coal from bed No. 2, and its heating value is correspondingly lower. It is considered a good grade of bituminous coal. Both these coals are coking coals and are used in the manufacture of gas.

BLACK CARBON.

Black Carbon, a drift mine on the Northern Pacific Railway about one-half mile west of Pittsburg, Wash. No. 63.

Operator: Black Carbon Coal Co.

Kind of coal: Bituminous.

Coal bed.—Only one coal bed has been worked in this mine, and at the time of the visit the mine was not operating. The bed strikes N. 15° W. and dips 40° E. The following section was taken where the sample was obtained:

Section of Black Carbon coal bed in Black Carbon mine.

No. 9892.

	Ft.	In.
Shale.		
*Coal		11
*Shale		¼
*Coal		8½
Shale		¼
*Coal		5½
Shale, lens		½
*Coal	1	3½
Shale		½
*Coal		5
Shale		½
*Coal		9½
Coal, bony		7
Clay, yellow		3
Shale, black.		
	5	7

Preparation for market.—No attempt was made in working this bed to separate any of the impurities from the coal in the mine. It was picked at the bunker over a 1½-inch bar screen.

Sample for analysis.—Sample 9892 was taken from chute 2½, about 6 feet above the gangway and 1,250 feet from the entrance to the mine. The bed contains several shale partings, most of which can be separated by careful picking and washing; the upper parting, however, is too thin to be separated and was included in the sample, an analysis of which is given on page 67.

Character and quality of the coal.—The coal is pitch black, and has a dark-brown streak and a vitreous luster. The lower bench of the coal is massive and dense, and breaks with an irregular fracture; the other layers are banded and laminated, and break with an irregular splintery fracture. The coal contains a small amount of moisture and does not crumble when exposed to the sun. Although the percentage of ash contained in it is somewhat high, it has a sufficiently high heating value to make it a fair commercial coal.

PITTSBURG.

Pittsburg, two slope mines at Pittsburg, on the Northern Pacific Railway. No. 64.

Operator: Coast Coal Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal beds.—Two coal beds are worked in this mine, the Lady Wellington and the Pittsburg. They strike N. 15° W. and dip 58° to 60° SW. The following sections were taken from the places where the samples were obtained:

Sections of coal bed in Pittsburg mine.

No. 9895, Lady Wellington coal bed.

	Ft.	in.
Shale.		
*Coal	4	11
Shale.		

No. 9894, Pittsburg coal bed.

	Ft.	in.
Shale.		
*Coal		10½
*Bone		¼
*Coal	1	2½
Shale and bone		4
*Coal		4
Shale, lens		1
*Coal		6½
Shale		1½
*Coal	1	2½
Bone	1	6½
	6	3¼

Preparation for market.—No attempt is made to separate the impurities from the coal in the mine. Coal from the Pittsburg bed is hoisted and dumped immediately on a 1½-inch bar screen, from which the oversize is hand-picked and the undersize is conveyed by flume to a washer at the bunkers. Coal from the Lady Wellington bed is hauled directly to the bunkers, where the lump coal is picked by hand and the fine coal is washed through two Forrester jigs.

Samples for analysis.—Sample 9895 was taken from the first cross-cut between chutes 32½ and 33, on the first level of the Lady Wellington bed. Both roof and floor are firm and do not mix with the coal in mining. Sample 9894 was taken at the face of the gangway just beyond chute 13½ on the first level of the Pittsburg bed. It contains several partings of shale and bone, most of which can be separated from the coal in preparation for market. The upper parting of bone was included in the sample. Both roof and floor of the bed are firm and do not mix with the coal. Sample 9893 was obtained by picking small quantities at intervals from the surface of the washed coal in the bins and on one of the railroad cars. The coal was still moist when the sample was taken and sealed in the can. The sample, containing about 65 pounds, was reduced to about ½-inch mesh and quartered. Opposite quarters were discarded and the remaining sample reduced to the size of a pea. This was again quartered and reduced in the usual way until about 4 pounds was left; this amount was sealed in the can and sent to the laboratory. The analyses of these samples are given on page 67.

Character and quality of the coal.—The coal from both of these beds is nearly pitch black, gives a dark-brown streak, and has a vitreous luster. It is massive, banded, and laminated, and breaks with an irregular, splintery fracture. It contains a small amount of moisture and does not crumble when exposed to the sun during transportation. Although it contains a large amount of ash, its heating value is high enough to make it a fair commercial coal. In almost every respect it resembles the coal from mine No. 1 at Ravensdale and the more mpure grades of coal in the vicinity of Bayne.

WILKESON.

Wilkeson, a water-level mine at Wilkeson, on the Northern Pacific Railway. No. 65.

Operator: Wilkeson Coal & Coke Co., Tacoma, Wash.

Kind of coal: Bituminous (coking).

Coal beds.—The coal beds worked in this mine are the same as beds Nos. 1, 2, and 3 (coking) at the Carbon Hill mine, Carbonado. The beds are folded along north-south axes so much that in some parts of the workings they dip to the east and in others to the west. They strike from due north-south to N. 30° W. and dip from 20° to 60° E. in the parts of the mine worked at the present time. They are fairly uniform in thickness in different parts of the mine, but the partings are somewhat irregular. The sections following were measured where the samples were obtained.

Sections of coal beds in Wilkeson mine.

No. 9905, bed No. 2.

	Ft.	In.
Coal.		
Shale		1½
*Coal		1
Shale		1
*Coal		9½
Shale, hard		½
*Coal		3
Shale, hard		1
*Coal		6
Shale, hard		3
*Coal	2	3
Shale, "mining," black		6 ±
Shale.		
	4	11½±

No. 9903, lower part of bed No. 2.

	Ft.	In.
Shale.		
Coal	1	7
Coal, bony	1	6
Coal, bony and streaks of coal	1	5
*Coal		9½
Coal, bony		½
*Coal		5
Shale, hard		1
*Coal	1	8½
Coal, bony		5
Shale, hard.		
	7	11½

No. 9901, lower part of bed No. 3.

	Ft.	In.
Shale, bony.		
Coal	1	
Shale		6
Coal	1	6
Shale, hard		¼
Coal		8½
Shale, lense		1
Coal		4
*Coal, bony	2	5
Shale, hard.		
	6	6¾

No. 9904, upper part of bed No. 2.

	Ft.	In.
Shale.		
Coal	1	7
Coal, bony	1	6
*Coal, bony and streaks of coal	1	5
Coal		9½
Coal, bony		½
Coal		5
Shale, hard		1
Coal	1	8½
Coal, bony		5
Shale, hard.		
	7	11½

No. 9902, upper part of bed No. 3.

	Ft.	In.
Shale, bony.		
*Coal	1	
Shale		6
*Coal	1	6
Shale, hard		¼
*Coal		8½
Shale, lense		1
*Coal		4
Coal, bony	2	5
Shale, hard.		
	6	6¾

No. 9900, bed No. 3.

	Ft.	In.
Shale, hard.		
*Coal		11
Shale		6
*Coal	1	
Coal, bony		1
*Coal		6
Bone		½
*Coal		7
*Coal, impure	1	9½
Coal, bony		3½
	5	8½

No. 9899, bed No. 7.

	Ft.	In.
Coal	1	6
Shale, hard		6
*Coal	3	6
Coal, bony		7
Bone.		
	6	1

Preparation for market.—No attempt is made to separate the partings from the coal in the mine. At the bunkers the coal is passed over a shaking screen with 1¾-inch perforations, after which the best lump coal is sent through a crusher and mixed with the washed coal from the first set of jigs, while the poorer grade of lump is stored in a separate bin and used for steam coal. The screenings are passed through five Forrester jigs, and are then rewashed through another set of jigs before being used for coke. The tailings from the second set of washers are stored in a separate bin and are used for the boilers. The equipment in use is capable of handling about 400 tons of coal a day. A new bunker, with a revolving dump and a Shannon jig, was being installed at the time the workings were visited. In this bunker the coal will be passed over a bar screen having 5½-inch spaces, from which the oversize will be picked and used for domestic coal and the undersize passed over a shaking screen with 3-inch perforations. The oversize from this second screen will be hand picked and conveyed to the bin for steam coal; the undersize will be again passed over a screen with ¾-inch mesh. Oversize from the ¾-inch screen is to be washed through a Shannon jig and the concentrates used for steam coal, and undersize will be washed through an improved Howe tub washer and used for coke. When the bunker is completed the capacity of the plant will be about 800 tons a day.

Samples for analysis.—Sample 9905 was taken from bed No. 2 about 50 feet up chute 105, on the southeast gangway. The bed contains several shale partings which can be separated at the bunkers, and these were not included in the sample. Soft shale, which breaks very readily, overlies the bed and necessitates the use of a fairly firm layer of coal as a roof. The bed is underlain by 6 inches of black shale, which is used as a "mining" and is removed by washing. Sample 9904 was taken from the upper part of bed No. 2, at the face of the gangway on the east water level, which, on the day the sample was taken, was 1,200 feet west and 1,500 feet north of the southeast corner of sec. 34, T. 19 N., R. 6 E. The bed is overlain by about 3 feet of bony coal and coal, which is badly crushed in this particular part of the mine and makes a very bad roof. Sample 9903 was taken from the bench underlying that from which No. 9904 was obtained, at the same place. This bed contains two layers of shale and bony coal that can be separated at the bunkers, and these were not included in the sample. It is underlain by 5 inches of bony coal, which mixes to some extent with the good coal in mining and must be removed at the bunkers. Sample 9902 was taken from the upper part of bed No. 3, about 50 feet up chute 19 on the southeast gangway. Three layers of shale are contained in the bed, but these impurities can be removed at the bunkers, and they were not included in the sample. Hard carbonaceous shale, which is crushed in some parts of the mine and mixes to some extent with the coal, overlies the bed. Sample 9901 was taken from the lower part of bed No. 3 at the place from which sample 9902 was obtained. The bed is underlain by hard shale, which is broken to some extent in parts of the workings and mixes with the coal. Sample 9900 was taken from the south end of the east gangway on bed No. 3, at a point about 3,000 feet north and 1,650 feet west of the southeast corner of sec. 34, T. 19 N., R. 6 E. The bed contains several layers of bone and shale which can be separated at the bunkers, and which were not included in the sample. Bony coal and shale, which mix to some extent with the coal and are removed at the bunkers, lie both above and below the bed. Sample 9899 was taken from a portion of bed No. 7 exposed in the roof of the gangway about 100 feet south of the rock tunnel from the west parting to the east gangways, and at a point about 650 feet west and 600 feet south of the north quarter corner of the section noted above. The bed is overlain by hard shale and coal, and underlain by bony coal, all of which are more or less crushed and mix with the coal in mining. The layer of coal next above the bed would probably be worked with this bed in mining. Sample 9898, consisting of about 100 pounds, was taken in small quantities and at random from the surface of the storage bins containing the rewashed coal, which is used in the coke ovens. The coal in the sample was broken to about ¾-inch mesh and reduced by the usual method of quartering to a sample of about 25 pounds, which was then ground to about the size of a pea and quartered by the usual method until the final sample of about 4 pounds was obtained. The coal was wet when sealed in the can. The analyses of these samples are given on pages 67–68.

Character and quality of the coal.—The coal from this mine is pitch black, gives a dark-brown streak, and has a vitreous luster. Most of the coal is minutely jointed and crumbles readily, so that the percentage of lump is very small. The texture of the coal is dense, and it breaks with a cubical fracture sometimes slightly irregular. It contains a small amount of moisture, and does not slack on exposure to the sun. Pure coal from the mine is probably low in ash and high in fixed carbon, and should have a very high heating value. Some of the benches, however, have considerably more ash than others and correspondingly lower heating value. The washed coal is used as a blacksmithing coal and is considered one of the best blacksmithing and coking coals in the State. The coal is fair bituminous, of about the same quality as that obtained from bed No. 3 at Burnett.

GALE CREEK.

Gale Creek, a slope mine at Wilkeson, on the Northern Pacific Railway. No. 66.

Operator: Gale Creek Coal & Coke Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal beds.—The three coal beds at this mine strike about N. 10° W. and dip from 26° to 60° SW., are uniform in thickness throughout the mine, and belong to the same group as that worked at Wilkeson and Carbonado. The mine had not been in operation for several months previous to the writer's visit. The following sections were taken where the samples were obtained:

Sections of coal beds in Gale Creek mine.

No. 9908, bed No. 1.

	Ft.	in.
Shale.		
Shale, slate-colored, fissile		1
*Coal	1	9
*Coal, soft		½
*Coal	1	6
Shale, hard, black.		
	3	4½

No. 9909, bed No. 2.

	Ft.	in.
Shale.		
Bone, soft		1
*Coal	3	
Shale, carbonaceous, "mining"		6
Shale, with bands of shale and coal.		
	3	7

No. 9910, Queen coal bed.

	Ft.	in.
Shale, hard.		
*Coal	1	11
Shale, carbonaceous		3
*Coal	1	4
Shale.		
	3	6

Preparation for market.—No attempt was made when the mine was operated to separate impurities in the mine. The coal was passed over a 1½-inch bar screen at the bunkers, after which the lump coal was picked by hand and the screenings were washed in a Jeffery tub washer.

Samples for analysis.—Sample 9908 was taken from bed No. 1 about 10 feet south of the auxiliary slope to the old No. 1 opening and in the first-level air course. The bed has one parting of soft coal which can not be separated from the hard coal and was included in the sample. The bed is overlain by about an inch of fissile shale which loosens from the roof after the coal has been drawn and mixes to some extent with it. The floor of the mine is a hard black shale, which is firm and does not mix with the coal. Sample 9909 was taken on the second level gangway of bed No. 2 in the new mine, about 100 feet south of the rock tunnel from this bed to the Queen. The bed is overlain by 1 inch of soft bone, which mixes more or less with the coal, and is underlain by 6 inches of carbonaceous shale, used as a "mining" and separated from the coal in preparation for the market. This bed has been considered the same as bed No. 1, but the workings on the two beds have not been connected and the relations between them have not been definitely established. Sample 9910 was taken from the Queen bed on the pillar between chutes 3 and 4, on the second level gangway north. The bed contains a shale parting near the center which can be removed in preparing the coal for the market and which was not included in the sample. Both the roof and the floor of the mine are firm and do not mix with the coal. Analyses of these samples are given on pages 68–69.

Character and quality of the coal.—The coal from these beds is pitch black, with a dark-brown streak and a vitreous luster. It is massive and laminated and breaks with a cubical fracture, occasionally slightly irregular. It contains a small amount of moisture and does not weather on exposure to the sun. All three beds have a fairly low percentage of moisture, but are somewhat higher in sulphur content than the best coal in this region. They have high heating values and should be classed as bituminous coal of high grade.

WILLIS.

Willis, a slope and water level mine at South Willis, on the Northern Pacific Railway, about 2 miles from Wilkeson. No. 67.

Operator: Commonwealth Coal Co., Wilkeson, Wash.

Kind of coal: Bituminous.

Coal beds.—These coal beds parallel the beds worked at the Wilkeson and Gale Creek mines, but are higher in the series. They strike about N. 10° W. and dip about 56° E. Two beds were being worked at the time the writer visited the mine, but the higher bed, which is known as No. 1, is not in its normal position and was not sampled. The following section was taken where the mine sample was obtained:

Section of Windsor coal bed in Willis mine.

No. 9906.

	Ft.	in.
Shale.		
Shale, carbonaceous		3
*Coal	4	4
Coal, soft, impure		2½
Shale		9½
Shale, sandy	1	6
Sandstone.		
	7	1

Preparation for market.—The coal from both the Windsor bed and from bed No. 1 is passed over a 1½-inch bar screen at the bunker. The oversize is picked and used solely as lump coal. The undersize is washed in a Robinson-Howe tub washer.

Samples for analysis.—Sample 9906 was taken from the Windsor bed 25 feet beyond chute 11 on the lower water-level gangway. The bed is overlain by carbonaceous shale and underlain by soft impure coal, both of which mix more or less with the coal and must be separated at the bunkers. Sample 9907, which was taken from the bunker containing washed coal, was composed of about 60 pounds of coal taken in small quantities and at random from the surface of the coal in the bins. The coal in the sample was reduced to ¾-inch mesh and quartered. Opposite quarters were discarded, the remaining sample ground to the size of a pea, quartered, reduced in the usual way until the final sample of about 4 pounds was obtained. The analyses of these samples are given on page 69.

Character and quality of the coal.—The color of the coal is pitch black, the streak dark brown, and the luster vitreous. It is massive and somewhat banded, and breaks with an irregular fracture. Moisture is present only in small amount in this coal, which does not slack on exposure to the sun, but the ash content is high. In general, the coal has about the same heating value as that from Pittsburg, which appears to be on beds of the same group. It is classed as a rather impure bituminous coal.

BRIER HILL.

Brier Hill, a water-level mine, about one-fourth mile west of Wilkeson, on the Northern Pacific Railway. No. 69.

Operator: Brier Hill Coal & Coke Co., Wilkeson, Wash.

Kind of coal: Bituminous.

Coal bed.—The coal bed upon which this mine was worked belongs to the group which occurs at the Gale Creek workings, but lies near the crest of the anticline on the opposite side of the syncline. The bed strikes N. 5° E. and dips 20° W. No work was being done on it at the time it was visited by the writer. The following section was measured where the sample was obtained:

Section of coal bed in Brier Hill mine.

No. 9897.

	Ft.	In.
Shale.		
Shale, hard		1½
* Coal, banded		6
* Bone		2
* Coal, banded		6
* Shale, hard		½
* Coal, banded		2
Shale, hard		1½
* Coal, banded	3	1½
Shale.		
	4	9

Preparation for market.—The bed has a low dip, and some of the impurities can be separated in the mine. In preparation for shipment the coal has been picked at the bunker.

Sample for analysis.—Sample 9897 was taken on the water-level gangway 500 feet south of the entrance of the mine. The bed contains several layers of hard shale and bony coal, much of which resembles the coal so closely that it can not be readily separated. Only the lowest parting in the bed was excluded from the sample. The analysis of this sample is given on page 69.

Character and quality of the coal.—The coal from this bed is grayish black and has a dark-brown streak and a dull luster. It is massive, distinctly banded, and laminated and breaks with a splintery fracture. It contains a small amount of moisture and does not slack when exposed to the sun. On account of the large amount of ash the heating value of the coal is about the same as that of an average subbituminous coal, but it should be classed as very impure bituminous coal.

SNELL.

Snell, a slope mine about 2 miles southeast of Wilkeson. No. 68.
Operator: Pacific Coal & Oil Co., Tacoma, Wash.
Kind of coal: Bituminous.

Coal bed.—One coal bed was worked at this mine when it was in operation. It had been closed for some time when the writer visited the place, and the slope was flooded nearly to the water level, and as most of the water-level gangway was caved in it was difficult to obtain a good sample. The bed strikes about N. 10° W. and dips 75° E., and is believed to underlie the beds worked at South Willis. The bed is somewhat disturbed where the sample was taken, and a full section could not be obtained. The section at this point is as follows:

Section of coal bed in Snell mine.

No. 9896.

	Ft.	in.
Shale.		
Shale, carbonaceous		2½
* Coal		7
Clay		½
* Coal	1	5
Shale, black		1
Sandstone.		
	2	4

Sample for analysis.—Sample 9896 was taken from the roof of the first water-level gangway 75 feet from the entrance and about 10 feet beyond the slope. A layer of clay near the middle of the bed can be removed, and was not included in the sample. The bed is overlain by about 2 inches of carbonaceous shale, which mixes with the coal and must be separated from it in preparing it for the market. A thin parting of black shale separates the coal at this point from a bed of massive sandstone underlying it. This sandstone was reported to be a lens in the main coal bed which had increased from a thickness of a few inches in the northern part of the mine to several feet at this place so that only the upper bench could be worked. The analysis of the coal sample is given on page 69.

Character and quality of the coal.—The coal in this bed is pitch black, gives a brown streak, and has a vitreous luster. It is minutely jointed, and can be readily crushed in the hand. The structure is slightly banded and laminated, and the fracture irregular. Analysis shows a slightly high percentage of ash, but this may be due to impurities which were mixed with the bed during the movement which crushed the coal. It contains a small amount of moisture and does not weather on exposure to the sun. It is reported to be one of the best blacksmithing coals in the State, and should be classed as a bituminous coal of fair quality.

CARBON HILL.

Carbon Hill, a series of drift and slope mines at Carbonado, on the Northern Pacific Railway. No. 70.

Operator: Carbon Hill Coal Co., San Francisco, Cal.

Kind of coal: Bituminous.

Coal beds.—More than a dozen coal beds have been worked at different times in this mine. Ten were being worked at the time of the writer's visit, and nine were sampled. Carbon River cuts diagonally across the beds, approximately along the line of a large fault which separates the more regular southern part of the formation from the folded part on the north. The strike of the beds on the south side of the river is fairly uniform, nearly north and south, and they dip from 60° near the north end to about 20° at the south end. North of the river the beds are somewhat closely folded, and locally they are offset by small faults. The beds were not numbered in reference to their position in the formation. Three slopes have been driven; one on the Wingate bed on the southwest side of the river, known as the No. 1 slope; another on the Wingate bed on the north side of the river, known as the No. 6 slope; and a third, called the Electric slope, on bed No. 1 at the end of a long rock tunnel, known as Mine No. 1 North. All the remaining openings are slightly above the river, and are spoken of as water levels. The beds and their partings are fairly continuous throughout the workings, but about one-half mile south of slope No. 1 the Wingate bed is offset by a diagonal dike and shows a different section south of the dike. The following sections were measured where the samples were obtained:

Sections of coal beds in Carbon Hill mines.

No. 9570, bed No. 11.

	Ft.	in.
Shale, black (poor roof).		
*Coal	1	1
Shale		3½
*Coal	1	½
Shale		2½
Shale, carbonaceous		2½
*Coal	1	
Shale		4
Coal		3
Shale (poor floor).		
	4	5

No. 9564, bed No. 5.

	Ft.	in.
Shale.		
*Coal	1	10
Shale, irregular		2½
Coal, impure		3½
*Coal, crushed	2	2½
Shale, hard, and some coal	1	3½
	5	10

No. 2480, bed No. 1.

	Ft.	in.
Coal, dirty	1	
Parting		½
*Coal	1	9
Parting		7
*Coal	1	8
Parting		¾
*Coal		8
Parting		1
*Coal	1	2
	7	¼

No. 9565, upper bench of coking bed No. 3.

	Ft.	in.
Shale, hard (poor roof).		
*Coal	1	5
Shale	1	
Coal	2	
Shale		2½
Coal	3	5
Coal, bony		7
Shale (poor floor).		
	8	7½

No. 552-D, coking bed No. 3.

	Ft.	in.
*Coal	1	10
Shale		4
*Coal	1	10
Shale		1¼
*Coal		10
Shale		1
*Coal		7
Shale		2
*Coal	2	4
	8	1¼

No. 9557, coking bed No. 3.

	Ft.	in.
Shale (poor roof).		
*Coal	2	7
Shale, hard		½
*Coal	1	6
Shale		1
*Coal		3
*Coal, fine-grained metallic		2½
*Coal		2½
Shale, hard		1
*Coal, bright, minutely jointed		11½
*Shale		¼
*Coal, bright, minutely jointed		6½
Shale		1
*Coal	2	2½
Shale (poor floor).		
	8	9¼

No. 9560, Wingate bed.

	Ft.	in.
Shale, hard.		
*Coal	4	6
Shale, hard and very smooth.		

No. 9558, Wingate bed.

	Ft.	in.
Shale, black.		
*Coal	5	1
Shale, black.		

No. 9556, bed No. 9.

	Ft.	in.
Shale, black.		
*Coal	3	7
Shale.		

No. 9572, bed No. 1.

	Ft.	in.
Shale, black.		
*Coal	2	9½
Shale and broken coal		2½
*Coal		11½
Shale		½
*Coal		5
Shale		2½
*Coal		3
Shale, hard		½
*Coal	2	
Coal, bony		5
Shale.		
	7	4

No. 9562, bed No. 4.

	Ft.	in.
Shale, carbonaceous.		
*Coal	1	7
Shale		½
*Coal, impure		3
Shale		½
*Coal	1	5½
Shale, "sulphur"		½
*Coal		6
Shale, "sulphur"		1
*Coal	1	7
Coal, bony	1	3½
	6	10½

No. 9555, lower bench of coking bed No. 3.

	Ft.	in.
Shale, hard (poor roof).		
Coal	1	5
Shale	1	
*Coal	2	
Shale		2½
*Coal	3	5
*Coal, bony		7
Shale.		
	8	7½

No. 9560, coking bed No. 1.

	Ft.	in.
Shale.		
*Coal, impure		3
*Coal, finely jointed and crushed	1	3½
Shale, irregular		1
*Coal, finely jointed and crushed		9½
Shale, black (poor floor).		
	2	5

No. 9601, Wingate bed in slope No. 1.

	Ft.	in.
Shale, hard.		
Shale, carbonaceous, thin streaks of coal		10
*Coal	4	1
Shale, hard.		
	4	11

No. 2459, Wingate bed.

	Ft.	in.
*Coal	4	11

Preparation for market.—The coal from this mine is prepared for the market by three processes. The first method is applied only to dry coal from the Wingate bed, which is passed over a 3-inch bar screen, the oversize being picked and dumped into the bin for lump. The undersize is picked by hand to remove fragments of mine timber and occasional pieces of shale from the floor or roof, which may mix with the coal, and is either sold as unwashed Wingate or flumed to the washer which handles the small coal from the wet Wingate dump. Coal from mine No. 6 and wet coal from mine No. 1 on the Wingate bed are handled by the second process, by which the coal is washed from the mine cars and passed over a bar screen having 2¼-inch and 1¾-inch openings; the oversize is picked twice to remove fragments of mine timber and impurities of shale and bone, and the undersize passed through two Robinson-Howe tub washers. Concentrates from the washer are carried by drags over draining screens having slits about 0.06 inch in width into bunkers for the washed Wingate coal, and the fine coal which passes through the slits is collected in a special settling tank constructed for the purpose. This fine coal is drawn from the bottom of the settling tank and again carried by drags over a draining screen, having slits about 0.03 inch wide. The coal which passes over the end of the screen is called "birdseye," that which passes through the screen is separated in large settling tanks and is called coal dust. Both the coal dust and the birdseye are sold in Seattle and Tacoma for use in automatic stokers for large heating plants. About 50 tons a day of coal dust and birdseye are saved from a total output of 800 tons. The coal from the other beds, all of which is treated by the third method, is passed over bar screens having 2¼-inch and 1¾-inch spaces. The oversize is picked three times and the resulting lump is known as Douty lump. The undersize is passed through a Robinson-Howe washer and is treated in the same manner as the Wingate coal.

A special set of Forrester jigs has been installed for the purpose of cleaning the coal for coking, but they were not in use at the time of the visit. Plate VIII, *A*, shows the town of Carbonado and the new beehive coke ovens of this company.

Samples for analysis.—Sample 9570 was taken 500 feet from the entrance to the gangway on bed No. 11, and about 40 feet above the gangway in chute 10. The coal bed is disturbed and considerably broken at this place. It contains three shale partings, which can be separated by careful picking and washing, and these were not included in the sample, but both the roof and floor, and the coal and shale which separate the bed from the floor, are badly broken and mix with the coal to a considerable extent in mining, constituting impurities which must be removed from the coal in preparing it for the market. Sample 9556 was taken from the south end of the gangway about 400 feet from the entrance to the water level on bed No. 9. The bed is overlain by fairly firm black shale, which does not mix with the coal. Sample 9564 was taken at the south end of the water-level gangway of bed No. 5 about 3,200 feet from the entrance. The bed contains an irregular layer of shale and some impure coal near the center, but both can be fairly well separated in preparation for the market, and they were excluded in the sample. The bed is overlain by shale and underlain by hard shale and thin layers of coal, all of which are fairly firm and do not mix with the coal. Sample 9572 was taken from the first level on bed No. 1 about 100 feet up chute 13 and 600 feet north of the bottom of the Electric slope. The bed contains several partings which, as they can be separated in preparation for the market, were not included in the sample. The carbonaceous shale overlying the bed and the bony coal underlying it are fairly firm, although locally they break and mix with the coal to some extent. Sample 2460 was taken by M. R. Campbell from bed No. 1 on the east dip, halfway between the synclinal point and the anticlinal end. All four partings in the bed were removed in sampling. Sample 9562 was taken from bed No. 4 about 200 feet up chute 14, north of the entrance to the gangway. The bed contains several layers of shale, which can be separated from the coal in preparation for the market, and these were not included in the sample. The roof is of carbonaceous shale and the floor of bony coal, which mix only slightly with the coal and can be removed at the bunkers. Sample 9565 was taken at the south end of the gangway on coking bed No. 3, at a point about 1,900 feet south and 100 feet west of the northeast corner of sec. 4, T. 18 N., R. 6 E. It was taken from the upper bench of the bed, which is overlain by hard shale—a very poor roof, which, in mining, mixes with the coal to a very considerable extent. Sample 9555 was taken from the lower bench of coking bed No. 3 at the place from which sample 9565 was taken. The bed contains a layer of shale, but as this can be removed in preparing the coal for the market it was not included in the sample. The lower layer of the bench is somewhat bony, but is mined with it, and is included in the sample. The coal in both samples from this bed was slightly moist, owing to seepage from the surrounding rocks, and the samples for analyses were sealed in the can while still wet. Samples 552–D and 787–D were taken by K. M. Way. The first-named sample was taken from the face of the gangway of coking bed No. 3 in the north workings, about 14,000 feet from the entrance to the No. 1 north tunnel. All the partings were separated from the sample. Analysis No. 787–D was made from a car of run-of-mine coal from bed No. 3 north (coking), after it had been shipped to Denver and before it had been put through the washer. Sample 9557 was taken from the north end of the gangway on coking bed No. 2, about 3,200 feet south and 100 feet west of the northeast corner of sec. 4, T. 18 N., R. 6 E. The bed contains several layers of shale, most of which can be separated when the coal is prepared for the market and were therefore not included in the sample. The second parting from the bottom, however, is very thin, and was included in the sample. Both roof and floor of the bed are of badly broken shale; they mix with the coal in mining to a considerable extent, and must be separated at the bunkers. Sample 9569 was taken from coking bed No. 1 at the end of the rock tunnel from coking bed No. 2. Coking bed No. 1 is believed to be one of the beds worked at the Wilkeson mine, but it is very much thinner at this place, probably on account of local movement along the bedding planes. The bed contains an irregular layer of shale near the bottom, which, as it can be removed in preparing the coal for the market, was not included in the sample; the upper part of the coal is somewhat impure, but was included in the sample. The coal in the two benches is finely jointed and crushed, indicating considerable movement, and is underlain by a very poor floor of black shale, also badly broken, which mixes with the coal in mining. Sample 9560 is a composite of two samples taken from the Wingate bed near slope No. 1. Half of the sample was taken from the third level at the south end of the gangway about 40 feet south of the main slope, and the other half from the same level at the end of the gangway 280 feet north of the slope. Both roof and floor are hard and firm and do not mix with the coal. Sample 9558 was taken from the third level in mine No. 6 on the Wingate bed, about 20 feet north of the slope in the first crosscut. Roof and floor are firm and do not mix with the coal except where there has been local disturbance. Sample 9601 was taken from slope No. 1 on the Wingate bed in the tenth crosscut between chutes 56 and 57 of the second level. The upper part of the coal bed in this part of the mine is replaced by soft carbonaceous shale containing thin streaks of coal, which breaks with the coal and must be separated at the bunkers. Along a definitely marked zone at the south end of the workings this shale contains a very large amount of gas under enormous pressure, which frequently blows out great masses of coal. Sample 2459 was taken by M. R. Campbell from the Wingate bed on the level 700 feet below the river, near a small fault.

The following samples were taken after the coal had been prepared for market by picking small lumps or small quantities at random from the surface of the bunkers or from the surface of railroad cars. In preparing each sample the coal was reduced to a ¾-inch mesh and quartered until about 25 pounds was left, after which it was ground to the size of a pea and quartered in the usual manner until a final sample of about 4 pounds was obtained. Sample 9566 represents about 125 pounds of Wingate lump coal taken from the surface of a 30-ton car. It was still moist when sealed in the can. Sample 9563 consisted originally of 80 pounds of dry Wingate coal passed over a 3-inch bar screen, sample 9567 of about 245 pounds of washed Wingate coal taken from the surface of the bunkers and from several railroad cars, and sample 9561 of 150 pounds of washed coal taken from the surface of 12 loaded railroad cars. It was raining at the time sample 9561 was taken, and the coal was sealed in the can while still wet. This sample probably consists for the most part of coal from the Wingate bed, but it may contain some of the Douty coal. Sample 9559 represents about 215 pounds of Douty washed coal taken from the bunkers and the surface of several railroad cars, and sample 9571 about 172 pounds of Douty lump coal taken from the Douty bin and from several cars which were being loaded. The coal in both samples was moist when sealed in the cans. For sample 9568, about 95 pounds of coal dust was taken from the surface of a railroad car containing about equal proportions of "birdseye" coal and coal dust just after it had been loaded. The sample was thoroughly mixed and quartered in the usual manner. The sample contained a very high percentage of moisture, most of which was retained after passing through the washer and was given off in air drying. The analyses of the samples from this mine are given on pages 69–72.

Character and quality of the coal.—The coal from this mine is pitch black, gives a dark-brown to black streak, and has a vitreous luster. It is massive and dense, and breaks with an irregular, hackly fracture. The coal from the Wingate bed breaks with an irregular, slightly conchoidal fracture along the lines of minor joints, resembling in this respect the coal of the McKay bed. The coal has a small amount of moisture and does not slack when exposed to the sun. Coal from the Wingate bed has a fairly small amount of ash and a heating value nearly as high as that of any coal in the State; coal from the other beds contains generally a greater amount of ash and is somewhat lower in heating value. All the coals are bituminous and of good grade, comparing favorably with many of the bituminous coals of the eastern part of the United States.

MELMONT.

Melmont, a slope and drift mine at Melmont, on the Northern Pacific Railway. No. 71.

Operator: Northwestern Improvement Co., Tacoma, Wash.

Kind of coal: Bituminous.

Coal beds.—Three coal beds are exposed in the mine, and the lower two were being worked at the time the mine was visited. Bed No. 1, the highest in the group, is not now being worked. No. 2, the middle bed, is being mined on a short water-level gangway. No. 3, the main bed of the mine, is worked at the present time in the first level. The beds strike N. 30° W. and dip 42° SW. Bed No. 3 is fairly uniform in thickness throughout the mine. The rocks of the entire region in which this mine is situated are very badly broken; joints occur close together and extend through both roof and floor, so that the blocks between the joints slide upon each other and cause a very strong squeeze in all parts of the workings. The following sections were made where the samples were obtained:

Sections of coal beds in Melmont mine.

No. 9579, bed No. 3.

	Ft.	In.
Shale (poor roof).		
*Coal, broken except lower 1 foot 3½ inches	5	5
*Shale		½
*Coal		11½
	6	5

No. 9576, upper bench of bed No. 2.

	Ft.	In.
Shale roof (poor).		
Shale, carbonaceous, soft		4½
*Coal	3	6
Dirt, black		4
Coal	5	3½
Shale		2½±
Coal.		
	9	8½±

No. 9577, bed No. 1.

	Ft.	In.
Shale, hard.		
Shale, soft	1	1
*Coal		7
Shale		1
*Coal		6½
Shale	1	5
*Coal	1	11
Coal, soft, clayey		1
*Coal		6
Shale, with thin layers of bony coal.		
	6	2½

No. 9578, bed No. 3.

	Ft.	In.
Sandstone.		
Shale (poor roof)	4±	
Shale, carbonaceous, soft	1	5±
*Coal	4	
Coal	2	
Shale.		
	11	5±

No. 9580, lower bench of bed No. 2.

	Ft.	In.
Shale roof (poor).		
Shale, soft, carbonaceous		4½
*Coal	3	6
Dirt, black		4
Coal	5	3½
Shale		2½±
Coal.		
	9	8½±

Preparation for market.—No attempt is made to separate impurities from the coal in the mine. At the bunkers the coal is passed over a shaking screen having perforations 2 inches in diameter, from which the oversize is picked on a link-belt picking table and conveyed to the bunkers, and the undersize sorted through a set of revolving screens. The different sizes from these screens are washed through a Forrester feldspar jig.

Samples for analysis.—Sample 9579 was taken from bed No. 3 on the first level north 50 feet above the gangway in chute 73. The bed contains a thin parting of shale which can not be readily removed in preparing the coal for the market, and it was therefore included in the sample. Both roof and floor are badly jointed at this place and mix with the coal to a considerable extent. Sample 9578 was taken from bed No. 3 on the first level north about 200 feet up the rise in the pillar between chutes 56 and 57. The workings were subjected to a very heavy squeeze at this point and only part of the bed could be sampled. The bed is overlain by 1½ feet of carbonaceous shale, very badly broken, which mixes to a considerable extent with the coal. The cap rock of shale which overlies this carbonaceous shale is also very badly broken, and makes a very poor roof. The floor of the mine is of shale and is probably broken like the roof. Sample 9576 was taken from the upper bench of bed No. 2 on the first water-level gangway north, 25 feet above the entrance to chute 2. The bed is overlain by an irregular layer of soft carbonaceous shale that mixes with the coal in mining and must be separated at the bunkers. The roof of the mine is also very poor and mixes to some extent with the coal. Sample 9580 was taken from the same place in the mine from which sample 9576 was obtained, from the lower bench of bed No. 2, which is separated from the upper bench by about 4 inches of black dirt that must be removed at the bunkers. The lower bench is underlain by a thin layer of shale which mixes to some extent with the coal. Analysis 10412 was made of a composite sample consisting of equal parts of the samples taken from bed No. 2. Sample 9575 represents about 200 pounds of coal taken from eight railroad cars, obtained by collecting small quantities at regular intervals from the surface of cars just loaded from the bunkers. The coal in this sample was reduced to ¾-inch mesh, and then quartered and reduced in the usual manner until about 25 pounds remained. This was ground to the size of a pea and quartered and reduced until the final sample of 4 pounds was obtained. The coal was wet when taken from the surface of the cars, and was sealed in the cans while still moist. Sample 9577 was taken from the north end of the first water-level gangway on bed No. 1 about 100 feet from the main rock tunnel. The bed contains several partings of shale and impure coal which can be separated from the coal in preparation for the market, and which were not included in the sample. At this point the bed is overlain by about a foot of soft shale, which makes a poor roof, inasmuch as it mixes to a considerable extent with the coal. The analyses of these samples are given on pages 72–73.

Character and quality of the coal.—The coal from bed No. 3 is pitch black, gives a black streak, and has a vitreous luster. It is dense and breaks with an irregular fracture. Joints break the bed very badly, so that it produces a very small amount of lump coal. The coal contains a small amount of moisture and does not weather on exposure to the air. It contains, however, a somewhat large amount of ash that can not be separated from the coal in preparation for the market. Coal from beds Nos. 2 and 3 is grayish black and dense, and breaks with an irregular fracture. It contains a greater amount of ash than bed No. 3 and a somewhat lower heating value. All these coals coke and are used as blacksmithing coal. They are of about the same quality as those at Carbonado, with the exception of the Wingate, and are regarded as a good grade of bituminous coal.

FAIRFAX.

Fairfax, a drift and slope mine at Fairfax, on the Northern Pacific Railway. No. 72.

Operator: Tacoma Smelting Co., Tacoma, Wash.

Kind of coal: Bituminous (coking).

Coal beds.—Three beds were examined in the mine and sampled. The lower bed, known as the blacksmith bed, was not being worked at that time. The middle, or bed No. 3, was being worked on the first level, and the upper, or bed No. 7, was being worked on the water level. The beds strike N. 30° W. and dip about 75° NE. Bed No. 3 is the only one at present worked to any considerable extent. Both the roof and floor of the bed are very firm, but they are not uniform. In some places the bed is only about a foot in thickness, and in other places it is nearly 4 feet. The following sections were taken where the samples were obtained:

Sections of coal beds in Fairfax mine.

No. 9607, bed No 3.

	Ft.	in.
Shale, very hard.		
*Coal, slightly bony		3
*Coal		6
Shale, hard		1
*Coal	2	11½
Coal, bony		3
Shale, hard, flinty.		
	4	½

No. 9608, bed No. 7.

	Ft.	in.
Shale (poor roof).		
*Coal, broken	5	3½
Shale, hard		4
*Coal	2	8½
Shale (poor floor).		
	8	4

No. 9609, blacksmith bed.

[South end of gangway.]

	Ft.	in.
Shale.		
Shale, carbonaceous		2½
*Coal	1	9
Shale.		
	1	11½

Preparation for market.—At the bunkers the coal is passed over a shaking screen having 1½-inch perforations. The oversize is hand picked to remove the shale partings and other impurities, then passed through a crusher, and thence conveyed to the washer. The undersize is washed through a Jeffery-Robinson washer and rewashed through two jigs.

Samples for analysis.—Sample 9607 was taken from bed No. 3 80 feet below the north water level in chute 8. The bed contains one shale parting, which can be removed in preparation for market and which was not included in the sample. Both roof and floor are very hard and do not mix with the coal in mining. Sample 9608 was taken from bed No. 7 at the end of the water-level gangway, about 75 feet south of the rock tunnel from bed No. 3. It contains a parting of shale near the center, which can be removed and which was not included in the sample. Both roof and floor are very poor; they mix to considerable extent with the coal and must be removed at the bunkers. Sample 9609 was taken from the blacksmith bed at the south end of a short gangway from a rock tunnel about 500 feet along the main gangway from slope No. 3. The bed varies in thickness and the coal for the sample was taken in two places within a few feet of each other. Both roof and floor are hard and do not mix with the coal except where local lenses of shale occur under the roof. Sample 9574 was made up from about 75 pounds of washed coal from the bunkers, which had stood in them under cover for some time. Small quantities of coal, all in fragments less than three-fourths of an inch in diameter, were taken at irregular intervals from the surface of the coal. The coal was thoroughly mixed and quartered in the usual manner until about 20 pounds were left; this was ground to the size of a pea and quartered until the final sample of 4 pounds was obtained. The analyses of these samples are given on page 73.

Character and quality of the coal.—The coal from this mine is pitch black, and has a black streak and a vitreous luster. It is massive and dense, and has a hackly fracture. It is very much broken in the bed and crumbles readily in the hand. Owing to its good coking qualities, nearly the entire output is coked in the ovens at the mine. A small amount, however, is sold occasionally for blacksmithing coal, for which purpose it is considered one of the best coals mined in the State. All the Fairfax coal is low in moisture and does not slack when exposed to the air, but that from bed No. 7 contains so large an amount of ash that, unless it can be thoroughly removed by washing, the coal will be of little value in the manufacture of coke. The coal from the blacksmith bed and from bed No. 3, however, have heating values nearly as high as any coal in the State. These coals are considered to be very good bituminous coal.

MONTEZUMA.

Montezuma, a number of drifts about 1 mile south of Fairfax, near the Northern Pacific Railway. No. 73.

Operator: Evans Creek Coal & Coke Co., Seattle, Wash.

Kind of coal: Semibituminous (coking).

Coal beds.—The four coal beds exposed in this mine are numbered in descending order. No. 1 is not being worked at the present time. All the beds are very thin, and if it were not for the steepness of the dip it would be very difficult to mine them. The beds strike nearly north and south and dip from 65° to 70° W. Most of the beds are fairly regular where they are not offset by faults. In a few places beneath some of the beds occur small lenses of coal, which can be mined with the rest of the bed. The following sections were measured where the samples were taken:

Sections of coal beds in Montezuma mines.

No. 9602, bed No. 1.

	Ft.	in.
Shale.		
Shale, soft		3½
*Coal		9½
Shale, hard		3½
*Coal	3	2½
Clay, yellow, soft		6
Shale.		
	5	1

No. 9605, bed No. 3.

	Ft.	in.
Sandstone, flinty.		
Shale, hard	1	6
*Coal, bright	1	6
*Coal, crushed	1	
*Coal, slightly bony		3½
Shale		3½
Coal and bone	1±	
Sandstone.		
	5	7±

No. 9603, bed No. 2.

	Ft.	in.
Sandstone.		
Shale, hard, with streaks of coal		7
Shale, soft, carbonaceous		2
*Coal	1	4
Shale		1
*Coal	1	1
Shale, soft, carbonaceous		2½
*Coal		2½
Shale, hard.		
	3	8

No. 9606, bed No. 4.

	Ft.	in.
Shale, carbonaceous		5
*Coal, small "niggerhead" near center (local)	1	11
*Coal, slightly bony		8½
Shale	1	
Coal	4	
	8	½

Preparation for market.—Coal from beds Nos. 3 and 4 is washed and stored apart from the coal from bed No. 2. All coal is passed over a shaking screen having 1½-inch perforations, from which the oversize is picked and used as domestic and steam coal, and the undersize washed through feldspar jigs and flumed to a bunker at the railroad track, where most of it is used in the manufacture of coke. A small percentage of the washed coal is sold for blacksmithing coal.

Samples for analysis.—Sample 9602 was taken from bed No. 1 at the entrance to chute 4, on the north water level. At this place the bed contains one shale parting which can be removed in actual mining, and this parting was not included in the sample. The bed is overlain by soft shale and underlain by soft clay, both of which mix with the coal in mining and must be separated at the bunkers. Sample 9603 was taken from bed No. 2, 5 feet above the first counter in chute 36. The bed contains two layers of shale, which can be removed without much difficulty and which were not included in the sample. It is overlain by bony coal and soft carbonaceous shale that mixes with the coal and must be separated from it at the bunkers. Sample 9604 was made up from 165 pounds of coal from bed No. 2 collected in small quantities at random from the bunker at the railroad track. It was thoroughly mixed and quartered and reduced until about 25 pounds was obtained; this was then ground to the size of a pea and mixed, quartered, and reduced until the final sample of about 4 pounds was procured. Sample 9605 was taken from bed No. 3 about 5 feet above the gangway in chute 11. This bed contains a layer of slightly bony coal near the bottom which can not be separated, and the entire layer was included in the sample. The main bed at this place is separated by a parting of shale from a lower bench of coal and bone, which is mined in part of the workings. Sample 9606 was taken from bed No. 4 just above the second counter on chute 6, at which place the bed is underlain by a local pocket of coal about 4 feet thick, an enlargement of a layer normally about 6 inches thick. The pocket coal was not included in the sample. Sample 9613 represents about 140 pounds of washed coal collected in small quantities at random from the surface of a bunker in which the coal from beds No. 3 and No. 4 is stored. The sample was prepared for the laboratory in the same manner as sample 9604. Analyses of these samples are given on pages 73–74.

Character and quality of the coal.—The coal from all four beds is pitch black, gives a black streak, and has a vitreous luster. It is massive and dense, and breaks with a hackly fracture. Because of its minute jointing it produces a very small amount of lump. It contains a very small percentage of moisture and does not weather when exposed to the sun. Bed No. 2 contains more ash than the other beds, and the amount of ash in the washed sample shows that this can be removed only with difficulty. The coal is considered a good coking coal and is used to a large extent as blacksmithing coal. Bed No. 3 is considered to be the best blacksmithing coal in the mine, and is reported to equal any blacksmithing coal in the State. The coal has a fairly high heating value and should be classed as a good grade of bituminous coal.

MASHEL.

Mashel, a tunnel mine located at Ashford, on the Tacoma Eastern Railroad. No. 74.

Operator: Western Steel Corporation, Seattle, Wash.

Kind of coal: Bituminous (coking).

Coal bed.—One coal bed is worked in this mine at the end of a long rock tunnel, which was driven to intercept the lower part of a bed known to outcrop along the crest of the ridge north of Ashford. The bed strikes N. 5° W. and dips about 38° E.; it is disturbed by a fault and the workings have not reached its normal position. The following section was taken at the end of the gangway about 4,400 feet from the entrance to the mine:

Section of coal bed in Mashel mine.

	Ft.	in.
Shale, crushed.		
*Coal (sample 9885)		9½
Shale, black		5
*Coal (sample 9885)	7	6
*Coal, bony (sample 9885)		2½
*Coal (sample 9885)	1	3½
Shale		3
*Coal, with few irregular layers of shale and bone (sample 9884)	5	1
Bone.		
	15	6½

Samples for analysis.—Sample 9885 was taken from the upper bench of the bed, which contains one parting of black shale that can be removed by careful picking and washing and was not included in the sample, and a layer of bony coal that can not be easily separated and was included in the sample. The bed was overlain at this place by shale so badly crushed that several feet break during mining and mix with the coal. Sample 9884 was taken from the lower bench of the bed, which is separated from the upper bench by about 3 inches of bony shale that can be separated from the coal. The analyses of these samples are given on page 74.

Character and quality of the coal.—The coal is pitch black, has a brown streak, and a vitreous luster. It is massive, and, in some parts of the bed, slightly banded. Most of the coal breaks with an irregular bright fracture. Although it contains a percentage of ash so high that the heating value of these two samples was greatly reduced, this impurity may possibly be removed by very careful and refined methods of washing. The coal appears to be a very good bituminous coal, and if a large percentage of the ash could be removed it would make good coke.

PROSPECT EAST OF ASHFORD.

An open cut in the SW. ¼ sec. 20, T. 15 N., R. 7 E., about 7 miles east of Ashford, Wash.

Kind of coal: Semibituminous.

Coal beds.—The coal bed strikes N. 73° W. and dips 15° SW. The section measured by J. B. Umpleby is as follows:

Section of coal bed in SW. ¼ sec. 20, T. 15 N., R. 7 E.

No. 6486.

	Ft.	in.
Shale.		
*Coal		6
Parting		2
*Coal		8
Parting		1
*Coal		4
Parting		10
*Coal	1	9
Shale	2	6
	6	10

Sample for analysis.—Sample 6486 was taken by J. B. Umpleby in 1908 from the place where he measured the section given above. All the partings were separated from the sample, the analysis of which is given on page 74.

Character and quality of the coal.—The physical properties of the coal are not known by the writer. The ratio of volatile matter to fixed carbon, however, is higher than in any coal commercially developed in the State, and the amount of ash in the coal is so high as to reduce its heating value to that of a low-grade coal.

SKAGIT COUNTY.

Numerous coal prospects and several old mines occur in the vicinity of Cokedale and Hamilton, in Skagit County, but none are being developed commercially at the present time. Owing to the fact that funds for the investigation were limited, the writer was unable to visit this region to obtain samples. Two samples of the Fairhaven coal from Cokedale (No. 80) were analyzed by the Bureau of Equipment[1] of the Navy Department at Washington, D. C., and these analyses are given on page 76 of this report. Although the coal is reported to be a good cooking and steaming coal, the Cokedale mine has not been in operation for several years. Gas occurs in some of the beds and makes mining very dangerous.

THURSTON COUNTY.

The coals of Thurston County are either subbituminous or on the border between subbituminous and lignite. All the mines worked at present are in the southern part of the county, between Tenino and Centralia. The relief of the region is low, and the outcrops are obscured by gravel, soil, and dense undergrowth. The geology of the coal-bearing beds has not been worked out, and their extent and

[1] Reports of the efficiency of various coals, 1896–1898, sections relating to coal from the annual reports of the Chief of the Bureau, 1902–3, and recent chemical analyses of coal at the navy yard, Washington, D. C., 1906, pp. 97 and 98.

relations to each other are not known. Dips of the beds at all the mines in this county visited by the writer are very low. The samples were collected during July and September, 1909, and February, 1910.

HANNAFORD NO. 1.

Hannaford No. 1, a slope mine at Tono, Wash., on a spur of the Oregon-Washington Railroad and Navigation Co., off the main line near Centralia. No. 75.

Operator: Washington Union Coal Co., Centralia, Wash.

Kind of coal: Subbituminous.

Coal bed.—Only one of the several coal beds exposed is mined at the present time. The bed is nearly horizontal, dipping only 4° NE. A slope has been driven about 1,500 feet in the lower portion of the bed, and two levels have been run to the north and three to the south. The mine has thus far been worked almost entirely in the lower bench of the bed, but the upper bench has been taken down in one or two rooms on the second level south and the company intends eventually to mine the entire upper bench. The following sections were measured at the places where the samples were taken:

Sections of coal bed in Hannaford No. 1. mine.

Nos. 9069 and 9573, upper bench.

	Ft.	in.
Shale.		
*Coal	4	5
Shale		1
	4	6

No. 9094, lower bench.

	Ft.	in.
Shale.		
*Coal	1	3
Shale		½
*Coal	1	8½
Clay		1
*Coal		9½
*Shale, brown		½
*Coal	1	8
*Shale		½
*Coal		3½
	5	11

No. 9095, lower bench.

	Ft.	in.
Shale.		
*Coal	1	3½
Shale, clayey		1
*Coal	1	9
*Clay, irregular layer		1
*Coal	3	2½
	6	5

No. 9096, lower bench.

	Ft.	in.
Shale		1
*Coal	1	2½
Shale, brown		1
*Coal	1	11½
Shale, carbonaceous		½
*Coal		11½
*Shale		½
*Coal	1	9½
Shale		½
*Coal		4
	6	6½

Preparation for market.—The coal from this mine is shipped as run-of-mine, and no attempt is made to separate the shale unless it parts readily from the coal in the mine or is of greater thickness than at any point from which the samples were taken. The entire output, aside from the coal consumed at the mine and in the company town, is used for steam coal by the Oregon-Washington Railroad & Navigation Co. and its connections.

Samples for analysis.—Samples 9089 and 9573 were taken from the upper bench, about 150 feet up the slope, in room No. 7 of the second level south. The 1-inch shale at the bottom of the bed forms a parting between this bench and the lower bench, which is the one worked in other parts of the mine. Sample 9095 was taken 200 feet from the gangway in room No. 12, on the first level south. The upper parting of this bench, which is the more regular, can be separated by picking, and was not included in the sample. Sample 9094 was collected at the entrance of room No. 12, on the first level north. The coal was slightly moist, owing to seepage from the overlying rocks, and was sealed in the can before it had a chance to dry; the analysis of this sample should therefore show a slightly higher percentage of moisture than the analysis of a sample in a normal condition. The bench at this place contains four partings, of which most of the upper two and part of the lower two can be separated from the coal by careful picking. In order to obtain a representative amount of ash, only the lower two partings were included in the sample. Sample 9096 was taken at the entrance to room No. 8, on the second level north, at which place the bed contains four distinct partings. In order to obtain a representative amount of ash in the sample, the third parting from the top was included. Analysis No. 8752 was made from a mixture of samples of run-of-mine coal from the lower bench of Hannaford No. 1 mine, taken at Pittsburg from two cars which had been on the road from three to five weeks. The analyses of these samples are given on pages 74–75.

Character and quality of the coal.—The coal is black in color and has a reddish-brown streak. It has a slightly banded structure and breaks with a conchoidal fracture. Because of its high moisture content, the coal weathers very readily when exposed to the sun, but it will stand transportation for some distance when shipped in closed cars. It should be classed as subbituminous coal.

Samples 9089 and 9057 were taken from the same place in the mine, but there is a very notable difference in the heating value and the amount of moisture of the air-dried samples. Sample 9089 was taken on July 21, when the coal was being mined from the upper bench in this room, and was exposed for a few hours during transportation to the office, but it was sealed immediately thereafter and was forwarded to the laboratory in an air-tight can. Sample 9573 was taken by removing the surface coal and cutting a fresh channel at the side of the old channel from which No. 9089 was taken. Previous to the time when it was obtained, September 29, it had been exposed to the mine atmosphere for about nine weeks. A comparison of the amount of moisture in these two samples as received and in samples as received from the other parts of the mine indicates that only a little moisture evaporated from either sample 9089 or sample 9573 during exposure to the atmosphere. The moisture in these two coals, as shown in the samples as received and in the same samples air dried, indicates that, although the total amount of moisture was the same, its relation to the coal had been changed so that it could not be driven off at the ordinary temperature used in the regular method of air drying.

PERTH.

Perth, a slope mine about 3 miles north of Centralia, on a logging road. No. 76.

Operator: Perth Coal Mining Co., Centralia, Wash.

Kind of coal: Subbituminous.

Coal bed.—Although several coal beds are exposed at this mine, the bed now being worked is the only one from which a sample could be obtained. This bed strikes N. 35° W. and dips 20° SW. The section was measured at a point 120 feet north from the foot of the slope and 40 feet up the rise from the first level gangway.

Section of coal bed in Perth mine.

No. 9178.

	Ft.	In.
Shale, compact, slate colored.		
*Coal		10
Clay, yellow		3½
*Coal		3½
Clay, yellow		3
*Coal		7
Clay, yellow		5
*Coal	2	8½
Shale, black, sandy.		
	5	4½

Preparation for market.—Shale from the roof is separated from the coal in the mine, and the coal is screened and picked by hand at the tipple.

Sample for analysis.—Sample 9178 was taken where the section given above was measured.

Three partings of yellow clay, all of considerable thickness, occur in the bed and must be separated in mining. When exposed to the air for a short time they swell to about one and one-fourth times their original thickness and become very soft and spongy. All three partings were excluded from the sample. The roof is of compact shale, which breaks off in large irregular slabs and mixes with the coal. The analysis of the sample is given on page 75.

Character and quality of the coal.—The coal is brownish-black and has a reddish-brown streak; it is massive and banded, and breaks with a conchoidal fracture. Owing to its high moisture content, which causes it to slack readily when exposed to the air, this coal should be classed as low-grade subbituminous coal.

BLACK BEAR.

Black Bear, a slope mine about 2 miles southeast of Tenino, on a spur of the Northern Pacific Railway. No. 77.

Operator: Tenino Coal & Iron Co., Tenino, Wash.

Kind of coal: Subbituminous.

Coal bed.—The coal bed from which the sample was taken was exposed in an abandoned mine east of the present slope. It was taken about 30 feet up the first room on the first level west of a slope sunk about 150 feet from the portal of the old gangway. The face from which the coal was obtained had been exposed to the weather for several years. The section measured is as follows:

Section of coal bed in Black Bear mine.

No. 9939.

	Ft.	In.
Shale.		
Shale, carbonaceous		3½
*Coal	2	1
Shale, spongy, varies from 1 to 2½ inches		1
*Coal		8½
Shale, spongy		2
*Coal		5
Shale		½
*Coal	2	5
Shale.		
	6	2½

Preparation for market.—The coal from this mine is prepared for market by screening and hand picking.

Sample for analysis.—Sample 9939 was taken where the section given above was measured. All three shale partings can be separated from the coal and were therefore not included in the sample. The sample was taken from the old workings, because a fault had been encountered in the new slope. The section of the bed exposed there was not typical. The analysis of this sample is given on page 75.

Character and quality of the coal.—The coal is brownish black and has a reddish-brown streak. It is massive and laminated and breaks with a conchoidal fracture. It contains a high percentage of moisture, and weathers on exposure to the air; probably 4 or 5 per cent of moisture had been removed from the coal by the circulation of mine air at the time it was taken, for it appeared to be slightly weathered. Like sample 9573, taken at the Hannaford mine, the condition of the moisture contained in the coal had apparently been modified in such a way that it could not be driven off by the usual method of air drying. This coal should probably be classed as low-grade subbituminous.

KING (GREAT WESTERN).

King, or Great Western, slope mine, 3 miles southwest of Tenino, on a branch of the Northern Pacific Railway. No. 78.

Operator: King Coal Co., Tenino, Wash.

Kind of coal: Subbituminous.

Coal bed.—The coal bed lies very nearly horizontal. At the entrance to the main gangway it dips very slightly (1° to 2°) to the east, while at the far end of the gangway the bed has about the same dip in the opposite direction, so that the gangway passes through a syncline near the center of the workings. The bed is thin, and is subjected to considerable pressure, so that a great deal of rock work is necessary in the gangways to keep them open. The following section was measured at the place where the sample was taken:

Section of coal bed in King mine.

No. 9987.

	Ft.	In.
Sandstone, white.		
Shale, hard		2½
*Coal		7
Shale, with irregular lenses of coal		3½
*Coal		4
Shale		1
*Coal	1	6
Shale, brown		1
*Coal	1	1
Clay, yellow, soft		4
Shale.		
	4	6

Preparation for market.—Impurities are for the most part removed at the bunker, where the coal is picked and washed.

Sample for analysis.—Sample 9987 was taken in room 10, about 100 feet up the rise from the twenty-fifth level north. Several partings of shale which occur in the bed may be separated from the coal by careful picking and washing, and they were, therefore, excluded from the sample. The analysis of the sample is given on page 75.

Character and quality of the coal.—The coal is brownish-black, and has a reddish-brown streak. It is massive and banded, and breaks with a conchoidal fracture. Owing to its high percentage of moisture, it slacks on exposure to the air, although not so readily as some of the other coals from the same region. Minute lenses of pyrite are probably responsible for a percentage of sulphur somewhat higher than that of other coals of this locality. The coal should be classed as low-grade subbituminous.

WHATCOM COUNTY.

The coals of Whatcom County have been mined in the vicinity of Lake Whatcom for many years. The only mine of commercial importance operating at the present time is the Blue Canyon mine (No. 79) at Park, near the shore of Lake Whatcom, which was not visited by the writer on account of the limited appropriation. The coal from this mine has been analyzed by the Bureau of Equipment of the Navy Department at Washington, D. C., and is given on page 76 of this report. It has a fixed carbon content equal to that of any of the high grade bituminous coals of the State, and a small amount of ash and moisture. Unless it is too badly jointed, the coal should hold up well in transportation to market.

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D.

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 475

THE

DIFFUSION OF CRUDE PETROLEUM THROUGH FULLER'S EARTH

WITH

NOTES ON ITS GEOLOGIC SIGNIFICANCE

BY

J. ELLIOTT GILPIN

AND

OSCAR E. BRANSKY

WASHINGTON

GOVERNMENT PRINTING OFFICE

1911

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ILLUSTRATIONS.

THE DIFFUSION OF CRUDE PETROLEUM THROUGH FULLER'S EARTH.

By J. Elliott Gilpin and Oscar E. Bransky.[1]

INTRODUCTION.

It is well established that the petroleum obtained from the sandstones of the Upper Devonian and Mississippian epochs, generally known as Pennsylvania oil, differs markedly from the natural oil found in the Trenton limestone, usually designated Ohio oil and Trenton limestone oil. Both of these oils, in turn, are distinctly different from the petroleum occurring in the loose sands and soft shales of California. The unconsolidated Tertiary clays, sands, and gravels in the southern United States, particularly in Texas, yield still another variety of petroleum, characterized by properties more or less different from those of any of the other oils.

Not only do these differences exist in oils found in separate regions, but there are extreme variations in color and specific gravity, as well as in chemical composition, in many oils occurring in neighboring localities. On the other hand, close resemblances are often found between petroleums of widely separated regions. Some of the South American and many of the European oils, for instance, have been found to possess properties very similar to those of the oils of the southern United States, while the oil from the "Corniferous" limestone of Canada closely resembles the Ohio petroleum.

These variations in the oils of the United States and other countries have been carefully studied by many investigators. Warren, Storer, Mabery, Pelouze, Cahours, Schorlemmer, Beilstein, Markownikoff, Engler, and Kurbatoff have devoted their lives to the subject. The questions that naturally arise in connection with the variations are, Are these differences fundamental? Is the Pennsylvania petroleum as distinctly different from the Ohio oil as one chemical compound is from another? In answer to these questions, the following extract

[1] Dissertation submitted to the Johns Hopkins University by Oscar E. Bransky for the degree of doctor of philosophy. This research was aided by a grant received from the C. M. Warren committee of the American Academy of Arts and Sciences.

from a paper read by Mabery[1] in 1903 before the American Philosophical Society is of considerable importance:

Now, after years of arduous labor, I have reached the conclusion that petroleum from whatever source is one and the same substance, capable of a simple definition—a mixture in variable proportions of a few series of hydrocarbons, the product of any particular field differing from that of any other only in the proportion of the series and the members of the series.

The evidence supporting this declaration has been and is accumulating constantly, and at the present time the view is generally accepted.

If petroleum, then, is everywhere one and the same substance, how can the extreme variations between the American oils be explained? Were the causes operating in the formation of the Pennsylvania oil, which is almost barren of sulphur and nitrogenous bodies, different from those acting in the production of the sulphur-bearing oils of Ohio or the heavy sulphur and nitrogenous oils of California?

To account for the formation of crude petroleum, two theories, the organic and inorganic, have been advanced. The Pennsylvania oil, according to these theories, may have been formed from either organic or inorganic substances, or from both. It is as yet impossible, however, to state conclusively from which of these sources the oil was derived. It is apparent, therefore, that the differences between the Pennsylvania and the Ohio, Texas, and California oils can not be explained on the assumption that the former was derived from organic remains and the latter from inorganic matter, or vice versa. If, however, the oils under discussion are organic in origin, they may have been formed either from vegetable or from animal remains. The following discussion is based on the assumption that these oils were derived from an organic source.

It has been suggested that the differences between these oils may be accounted for by assigning a vegetable origin to the Pennsylvania oil and an animal origin to the others. Mabery[1] states that—

It would seem that the small proportion of these bodies [sulphur, nitrogen, and oxygen compounds] in the Pennsylvania oil, as compared with the larger proportions in the limestone oils and California oil, should be strong evidence in favor of a different origin, that the Pennsylvania oil came from organic vegetable remains, which should permit of the small amounts of sulphur and nitrogen compounds from this class of oils.

Newberry, Peckham, Orton, and other geologists also favor the view that the Pennsylvania oil is of vegetable origin and is derived from the organic matter of the bituminous shales of the Devonian period.

The association of this oil with a vegetable source has been compelled, it seems, first, by the fact that the oil is of a different character from the limestone oils of Ohio and those of Texas and California;

[1] Proc. Am. Philos. Soc., 1903.

second, by the fact that the Pennsylvania petroleum is found in strata that bear but few fossils; third, by the belief that the Chemung and immediately overlying formations are barren in animal organic remains; and fourth, by the existence of large quantities of microscopic fossils, whose origin many believe is vegetable, in the black shales of the Lower and Middle Devonian formations to which many investigators are inclined to refer the origin of the Pennsylvania oil.

Pennsylvania oil differs markedly from the Ohio, Texas, and California oils. Investigation has shown that it contains a much larger proportion of the paraffin hydrocarbons and a much smaller percentage of benzene, unsaturated hydrocarbons, sulphur, and nitrogenous bodies. It is further generally admitted that the Pennsylvania oil was not formed in place. These two facts aided strongly in assigning a vegetable origin to this oil.

To what strata should the source of the oil be referred? The great coal formations of Pennsylvania, lying above the Chemung, seem at first glance to offer a solution. It is a notable fact, however, that these formations have not, up to the present time, been connected, either chemically or geologically, with the Pennsylvania oil. The possibility exists that it may have been formed from vegetable remains in the Carboniferous formations above and reached its present position in the Chemung by downward diffusion. This view rests on the physical fact that a liquid diffuses by the force of capillarity in all directions, downward as well as upward. Little attention has been given to this possibility, but it seems to deserve a careful study. Owing, however, to the universal association of water under hydrostatic pressure with natural oil and gas, the migration of the latter is generally upward. This fact is attested by the accumulation of oil in anticlinal folds when water is present and by the existence of the remarkable gushing oil wells. That the Pennsylvania oil, if not formed in place, ascended to its present location seems, therefore, more probable.

In what strata below the Chemung, then, was the oil originally produced? It has been previously mentioned that a number of investigators refer the source of the oil to the black shales of the Lower and Middle Devonian. The organic matter of these shales is composed largely of microscopic sporangites, which suggest the existence, according to Orton, of masses of floating vegetation, or sargasso seas. According to this view the Pennsylvania oil is of vegetable origin and its primitive abode was in the shales of Devonian age lying below the Chemung formation, to which it ascended under the influence of natural agencies. A second view, which assigns an animal origin to the oil, is that it was formed in the fossil-bearing strata of Chemung age and diffused to the sandstone reservoirs in which it is now found, and that during such a diffusion its original character was changed.

Prof. C. K. Swartz, of Johns Hopkins University, who has made a critical study of the Chemung strata in Maryland, states that fossil remains exist in considerable abundance in the strata of this age in Maryland and adjoining areas. In Pennsylvania the corresponding strata have been found to bear many fossils. It is possible, therefore, that the oil may have formed in these strata and then diffused to strata barren of fossil remains, where it now exists.

The evidence accumulated in this investigation seems to show that it is not necessary to assign a vegetable origin to the Pennsylvania oil to explain the differences between it and the oils of Ohio and California. It is clear from the results of this and other investigations that when such oils as those of Ohio, California, and Texas, which seem to be animal in origin, are allowed to diffuse through such porous media as fuller's earth, they yield oils very similar to those of Pennsylvania. By assuming, therefore, that the Pennsylvania oil migrated from some primitive source, in which it may have been formed from animal remains, through shales, limestones, and sandstones, its peculiar character can be understood.

Wherever the original home of the oil may have been, it seems probable that it migrated to its present location from below. It is with the changes occurring in crude petroleum as a result of such a migration through porous strata that the present investigation is primarily concerned.

In 1897 David T. Day,[1] on his own observations and those of John N. MacGonigle, proposed the view that the Pennsylvania oil, at some past time, possessed properties very similar to those of the Ohio oil, but that in its migration to its present abode from strata below its character was changed. Guided by this view, Day conducted, in the laboratories of the United States Geological Survey, an investigation into the changes occurring in crude petroleum when allowed to diffuse through porous media, such as fuller's earth. He demonstrated clearly that an oil resembling the light Pennsylvania oil could be readily produced in the laboratory from the heavier crude Ohio oil. Glass tubes were packed firmly with the dry earth, through which the crude oil diffused by its own force of capillarity. From the earth of the upper sections of the tubes very light, even colorless, oils were liberated by treatment with water; from the earth of the lower sections of the tubes much darker and heavier oils were obtained.

The fractionation, it will be observed, is effected entirely by capillarity; oils with different surface tensions rise with different velocities through the capillary openings, such as the fine interstices and minute pores of the fuller's earth. A separation of the various constituents making up the complex of any one oil is thus brought

[1] Proc. Am. Philos. Soc., 1897.

about. The view once held that this phenomenon is chemical was clearly disproved by Engler and Albrecht[1] in 1901, and later by other investigators.

Any medium, therefore, sufficiently fine grained and porous to afford capillary spaces, causes a separation of the constituents of any mixture, provided they possess different surface tensions. The compact sandstones, shales, and limestones that recur in many cycles throughout the earth's crust present an excellent medium for the separation of the constituents of so complex a mixture as petroleum. The force of capillarity, assisted by the hydrostatic pressure of the water occurring in the interior of the earth, acting over vast periods of time, is, it seems safe to state, sufficiently powerful to transport the oil from the lower strata to those above. That the conditions, therefore, to cause such a migration, with the consequent fractionation of the original oil, are abundantly present appears extremely probable.

The members composing the natural oil may be grouped under the following general heads: Paraffin; aromatic, unsaturated hydrocarbons; and sulphur, nitrogen, and oxygen compounds. The behavior of the paraffin and unsaturated hydrocarbons when subjected to fractionation will be considered first.

Day early observed that the unsaturated hydrocarbons are less diffusible than the paraffin hydrocarbons. Later, Gilpin and Cram[2] demonstrated that when petroleum is allowed to diffuse through tubes packed with fuller's earth, the unsaturated hydrocarbons collect in the earth of lower sections of the tubes, while the paraffins tend to accumulate in the lightest fraction at the top of the tube. In the present investigation these results have been fully confirmed. On pages 44–45 are given the bromine absorption values and the percentages by volume absorbed by concentrated sulphuric acid of the various oils obtained from definite sections of a tube. These figures indicate conclusively that the amount of unsaturated hydrocarbons is much greater in the oils from the lower sections of the tube than in the lightest fractions at the top of the tube. Furthermore, the bromine absorption values for the oils of similar fractions of the first, second, and third fractionation, given on page 46, show that in the progress of the fractionation more and more of the unsaturated hydrocarbons are removed. Herr,[3] in Russia, has likewise observed that these hydrocarbons are less diffusible than the paraffins.

An interesting confirmation of these experiments in nature has been recently presented by Clifford Richardson and K. G. MacKenzie.[4] They found that a colorless natural naphtha from the Province of

[1] Zeitschr. angew. Chemie, 1901, p. 889.
[2] Bull. U. S. Geol. Survey No. 365, 1908.
[3] Petroleum, August, 1909.
[4] Am. Jour. Sci., May, 1910.

Santa Clara, Cuba, contained practically no unsaturated hydrocarbons but was almost entirely a mixture of naphthenes and paraffins. Concentrated sulphuric acid absorbed but 0.76 per cent by volume, while fuming sulphuric acid absorbed only 1.8 per cent. With the naphtha were obtained water and an emulsion of water, oil, and clay. These investigators are of the opinion that the naphtha was "undoubtedly formed by the upward filtration of heavy petroleum through the clay stratum, similar to the fuller's earth filtrations of Gilpin and Cram, and the light naphtha in the upper part of the stratum was afterwards partly liberated by saline waters, the oil remaining in the clay forming, with water, the emulsion."

A comparison of the proportions of the unsaturated hydrocarbons in the Ohio and Pennsylvania oils shows that the latter contain a much smaller percentage of these hydrocarbons. By assuming that the Pennsylvania oil diffused upward through such porous media as shales and limestones to its present location in the sandstones, it is possible to account for the smaller amounts of the olefines in it on the basis of the experimental work described above. In its passage through the capillary interstices of the clays, limestones, and sandstones, a fractionation, resulting in the removal of the unsaturated hydrocarbons, probably occurred. It is reasonable to conclude, therefore, that the variation in the content of unsaturated hydrocarbons between the Ohio, Texas, and California oils, on the one hand, and the Pennsylvania oil, on the other, can probably be accounted for by assuming that the Pennsylvania oil was subjected to capillary diffusion at some time in its career. That the light-colored naphthas occurring in different parts of the world were originally darker and heavier oils, and that their primitive character was changed by diffusion through media possessing the power of fractionation seems very probable.

The behavior of the aromatic hydrocarbons, in particular benzene, in passing through fuller's earth constitutes one of the subjects of this investigation. The results of this study, given in detail on pages 15–28, indicate clearly that benzene, like the olefines, tends to collect in the lower sections of a tube of fuller's earth through which the benzene, in solution, is allowed to diffuse. That the aromatic hydrocarbons in the natural oil behave in a similar manner has not yet been decided. The proportion of these hydrocarbons in the Illinois oil investigated was too small to enable us to determine accurately their amounts in the fractions obtained by the capillary diffusion of the crude oil. The ordinary methods, such as nitration with the mixture of nitric and sulphuric acids, and sulphonation, employed for the quantitative determination of the aromatic hydrocarbons, could not be used in this work, owing to the fact that these reagents readily affect the unsaturated hydrocarbons as well. A study of the conduct of the aromatic hydrocarbons in the natural oil containing large amounts of them will be undertaken in the near future. It is probable, however, that the benzene and homologous compounds in crude petroleum behave like the unsaturated hydrocarbons.

The presence of larger amounts of aromatic hydrocarbons in the Ohio than in the Pennsylvania petroleum, and of still larger amounts in the California and Texas oils, seems to afford further evidence in favor of the view that the Pennsylvania oil has undergone much greater diffusion, and consequently greater fractionation, than any of the other oils.

The conduct of the sulphur compounds in petroleum in the process of diffusion is similar to that of the unsaturated hydrocarbons. On page 46 the percentages of sulphur present in the oils from different parts of the tube and different stages of fractionation are tabulated. One series of figures will be given here to show the behavior of the sulphur compounds.

Behavior of sulphur compounds in fractionation.

	Per cent of sulphur.
First fractionation (lot 6):	
Fraction A	0.04
Fraction B	.05
Fraction D	.09
Fraction E	.16
Second fractionation: Fraction A	.04
Third fractionation: Fraction A	.003

It is clear from these figures that the sulphur compounds, like the unsaturated hydrocarbons, tend to collect in the lower sections of a layer of fuller's earth through which petroleum is allowed to diffuse.

In 1902 Clifford Richardson and E. C. Wallace,[1] in an investigation on the occurrence of free sulphur in Beaumont petroleum, passed the oil upward through a fuller's earth filter similar to one described by Day at the petroleum congress in Paris in 1900, and obtained distinct fractionation. The percentages of sulphur in the crude oil and in the oils obtained by this fractionation were determined. The results are given in the following table:

Percentages of sulphur in crude oil and after fractionation.

	Specific gravity $\frac{25°}{25°}$	Per cent of sulphur.
Crude oil	0.9140	1.75
First fraction	.8775	.80
Second fraction	.8986	.91
Third fraction	.9038	1.04

[1] Jour. Soc. Chem. Ind., March, 1902.

It seems reasonable to assume from these results that the variations in the sulphur content between the Pennsylvania and Ohio oils may be satisfactorily explained by the view that the former oil, as previously stated, diffused from other strata to its present location, and in its migration a large part of its original content of sulphur was removed. Further work on this point will be undertaken in the Johns Hopkins University laboratory.

No careful study of the behavior of the nitrogen and oxygen compounds in petroleum diffusing through a porous medium has yet been undertaken, but such an investigation will be pursued in the same laboratory later. It is probable that such an investigation will show that the nitrogen compounds act like the sulphur and unsaturated compounds.

OBJECT OF THIS INVESTIGATION.

The present investigation was undertaken for the immediate purpose of studying the changes occurring in the crude Illinois oil when allowed to diffuse through fuller's earth. The more distant but more fundamental object was to gain further insight into the causes of the variations among the oils of this country.

PRELIMINARY EXPERIMENTS.

RELATIVE AMOUNTS OF OIL LOST IN HEATED AND UNHEATED FULLER'S EARTH.

Before the actual investigation of the Illinois oil was undertaken, experiments were made to determine the relative amounts of oil lost in heated and unheated fuller's earth.[1] In the work of Gilpin and Cram the earth was always heated until geysers ceased to form and then allowed to cool for several hours. The purpose of heating the earth was to obtain larger yields of oil, but toward the close of their investigation it became apparent that the amount of oil lost in unheated fuller's earth was not as large as they had supposed it to be. As much time and labor is consumed in the process of heating and then cooling the earth, it seemed advisable to settle this point at the outset.

The apparatus employed for the present investigation was essentially the same as that used by Gilpin and Cram. Figure 1 shows the arrangement of the diffusion tubes. A, A, A, A are tin reservoirs made to hold somewhat more than a liter. The tin tubes B, B, B, B, 5½ feet long and 1¼ inch in diameter, rest upon narrow tin supports placed upon the bottom of the reservoirs, and are connected with the branched glass tube F by suction tubing fitted with pinchcocks at

[1] The fuller's earth employed in this work was generously supplied by the Atlantic Refining Co., of Philadelphia.

E, E, E, E. The branched glass tube is connected with the large tank C, which serves to maintain fairly constant pressures; C is in turn joined by the glass tube D to a manometer, and the latter is connected with the Chapman pump. Any number of tubes may be set up in series under the same diminished pressure.

After the tubes are closed at their lower ends with grooved corks covered with muslin to prevent the earth from sifting out, they are packed to the desired firmness with the fuller's earth. Each tube is then placed in its own reservoir, containing the oil to be fractionated. When they are connected to the branched tube F, the pressure in the system of tubes is reduced by the suction pump. The oil rises at first rapidly; then its diffusion gradually diminishes in power. When the reservoirs are almost exhausted, the tubes are disconnected and

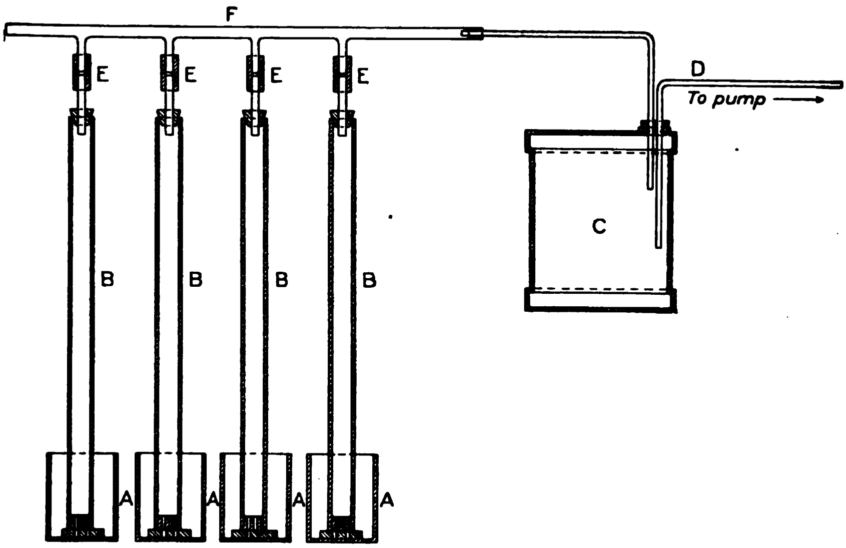

FIGURE 1.—Arrangement of diffusion tubes. See text for explanation.

clamped with the bottom ends up above shorter tubes of the same diameter, into which the oil-laden earth is allowed to slide. These shorter tubes are made of two curved pieces, joined at the bottom by a cap and held together at the top by a ring. The cylinders are opened by slipping off the ring and cap and removing one of the curved pieces, and the earth is divided into the desired sections. When water is added in portions to the earth and the two mixed thoroughly, the oil is displaced and is drawn off in separate portions.

Six tubes packed with heated fuller's earth were set up alternately with six tubes filled with the unheated earth. Each tube was placed in its own reservoir containing 950 cubic centimeters of crude oil. The oil was allowed to diffuse upward through the tubes under diminished pressure. The oil in the reservoirs was not exhausted ur

16 hours had elapsed. As the tubes did not rest directly upon the bottoms of the reservoirs, a small amount of oil remained in each; the volumes were subtracted from the volumes originally supplied. The earth from each tube was shaken into a bucket, and the oil was recovered by displacement with water, as described above. The results of these experiments are arranged in the following table:

Pennsylvania oil lost on heated and unheated fuller's earth.

Heated fuller's earth.

Tube.	Weight of fuller's earth (grams).	Oil absorbed by earth (cubic centimeters).	Oil recovered (cubic centimeters).	Oil lost.	
				Cubic centimeters.	Per cent.
1	1,005	850	450	390	46
3	1,000	792	460	332	41
5	1,035	850	500	350	41
7	1,070	865	450	415	48
9	1,035	813	430	383	47
11	1,045	885	530	355	41
	....	5,055	2,830	2,225	44

Unheated fuller's earth.

Tube.	Weight of fuller's earth (grams).	Oil absorbed by earth (cubic centimeters).	Oil recovered (cubic centimeters).	Oil lost: Cubic centimeters.	Oil lost: Per cent.
2	1,075	917	585	332	36
4	1,095	853	562	291	34
6	1,065	840	500	340	42
8	1,045	814	435	379	46
10	1,035	873	510	363	41
12	1,055	850	485	365	41
	....	5,147	3,077	2,070	40

The petroleum employed in the above-described experiments was a dark-green oil from Venango County, Pa., possessing a specific gravity of 0.810. As the Illinois oil which was used in the fractionation proper, described later, differs materially from the Pennsylvania petroleum, further experiments were undertaken to determine the relative amounts of this oil retained by heated and unheated earth.

Ten tubes, of which five were packed as uniformly as possible with fuller's earth that had been heated until geysers ceased to form and the other five with unheated earth, were placed in reservoirs, each containing 950 cubic centimeters of Illinois oil, having a specific gravity of 0.8375. When the oil was entirely absorbed, the tubes were taken down, the oil-laden earth was shaken into two breakable cylinders, and divided into six sections—A, 10 centimeters in length, measured downward from the level to which the oil had ascended; B, the next 15 centimeters; C, 20 centimeters; D, 30 centimeters; E, 35 centimeters; F, the remainder of the earth to the bottom of the tube. Section F was entirely discarded.

The earth was then treated with separate portions of water. The oils displaced by the successive additions of water were collected separately and are designated in the table below as A^1, A^2, B^1, B^2, and so on; A^1 is the oil first displaced, A^2 the oil next expelled by further additions of water. The volumes and specific gravities of the recovered oils were determined. The results are expressed in the following table:

Fractions of Illinois oil recovered after diffusion through fuller's earth.

Fraction.	Heated fuller's earth.		Unheated fuller's earth.	
	Specific gravity.	Volume (cubic centimeters).	Specific gravity.	Volume (cubic centimeters).
A^1	0.8287	100	0.8320	72
A^2			.8352	22
B^1	.8390	157	.8405	184
B^2	.8485	35	.8451	124
C^1	.8441	280	.8443	270
C^2	.8507	67	.8495	147
D^1	.8450	393	.8483	368
D^2	.8490	132	.8517	210
E^1	.8537	339	.8500	360
E^2	.8564	174	.8569	185
		1,701		1,942

In these experiments the percentage of oil lost in the unheated earth is less than the percentage of oil lost in the heated earth. Gilpin and Cram, employing heated earth, recovered in one test 5,951 cubic centimeters from 9,070 cubic centimeters, and in another 5,415 cubic centimeters from 8,915 cubic centimeters, the amount of oil lost in the earth in the first test corresponding to 34 per cent and in the second to 39 per cent. It is clear, therefore, that there is not sufficient compensation, if any, for the time and labor spent in heating the earth. In the investigations that followed the unheated fuller's earth was always used.

THE DIFFUSION OF BENZENE IN SOLUTION THROUGH FULLER'S EARTH.

In order to deal more intelligently with the fractionation of the crude Illinois petroleum, it seemed advisable to study the behavior of the individual aromatic hydrocarbons, especially benzene, both alone and mixed with paraffin hydrocarbons, when allowed to diffuse upward through fuller's earth. Gilpin and Cram established the fact that the paraffin hydrocarbons tend to collect in the lightest fractions at the top of the tube. Their method consisted in distilling by heat six samples of oils of different specific gravities, each 300 cubic centimeters in volume, and collecting 10 fractions between definite intervals. Five of these samples consisted of oil partly fractionated by fuller's earth and the other sample consisted of the crude oil. The specific gravity and viscosity of each fraction were determined; then to 30 cubic centimeters, or to all there was the amount was less than 30 cubic centimeters, an equal volume of concentrated sulphuric acid (specific gravity 1.84) was added, and the two were shaken by a machine for half an hour or longer. The volume of the oil unaffected by the acid was measured, and by subtraction the volume of oil absorbed was calculated. This latter volume represents only approximately the percentage of unsaturated hydrocarbons present in the oil, because sulphuric acid of this strength readily dissolves benzene when the two are thoroughly shaken.

In this investigation various solutions of benzene and a refined paraffin oil, boiling between 160° and 240° and only slightly attacked by sulphuric acid, were made up and allowed to rise in tubes packed with unheated fuller's earth. The pressure in the system was reduced very little, because the liquid, under a greatly diminished pressure, rose too rapidly. About 24 hours elapsed before the oil in the reservoirs was exhausted.

The earth in each tube was shaken out and divided into six sections. Beginning at the uppermost point to which the oil had ascended grade A consisted of the first 8 centimeters, grade B of the next 8 centimeters, grade C of 18 centimeters, grade D of 30 centimeters, grade E of 35 centimeters, and grade F of the remainder of the earth, depending on the height to which the oil had ascended. This division is the same as that used by Gilpin and Cram. The oil in the earth was displaced by water and drawn off.

The specific gravity of each fraction was determined by means of the Mohr-Westphal balance at exactly 20° C. The fourth decimal place is not to be considered as strictly accurate, but gives a closer approximation to the truth than if it were entirely discarded.

The viscosity was determined by means of the viscosmeter described by Ostwald and Luther and modified by Jones and Veazey.[1] The time taken for measured volumes of the oils to drain from the small bulb, whose capacity was 4.5 cubic centimeters, was compared with the time required for a similar amount of water to run through. These values were substituted in the equation—

$$y=y_0\frac{TS}{T_0S_0}$$

in which—

y_0 =coefficient of viscosity of water. For this, 0.01002, the value obtained by Thorpe and Rodger,[2] was used.

T =time of flow of liquid under examination.

S =specific gravity, measured at 20° C., of liquid under examination.

T_0 =time of flow of water.

S_0 =specific gravity of water. Since the balance was calibrated for water 20° C., the value for S is unity.

y =coefficient of viscosity of oil under examination.

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[1] Zeitschr. physikal. Chemie, vol. 61, p. 651.

[2] Philos. Trans., vol. 185A, 1894, p. 397.

The amount of benzene present in each fraction was determined by shaking the oil with an excess of ordinary concentrated sulphuric acid (specific gravity 1.84) for periods of time varying from 30 to 60 minutes, until there was no further diminution in the volume of the oil.

The results of the experiments tabulated below demonstrate the power of this acid to dissolve benzene, forming benzene-sulphonic acid:

Action of concentrated sulphuric acid (specific gravity 1.84) on benzene when shaken by machine.

Benzene taken (cubic centimeters).	Acid taken (cubic centimeters).	Time shaken (minutes).	Benzene dissolved.	
			Cubic centimeters.	Per cent.
25	25	30	7	28
25	50	30	18	72
25	75	30	25	100

The reagents usually employed for removing benzene are a mixture of fuming nitric and concentrated sulphuric acid. The work of Worstall,[1] Francis and Young,[2] and others shows that such a mixture readily attacks the paraffin hydrocarbons, especially at higher temperatures, forming nitro-derivatives and also oxidizing them to a considerable extent. Furthermore, in working with this mixture the oil must be kept at a low temperature to prevent a violent reaction, which results usually in the decomposition of the oil. In this work, therefore, in order to avoid the danger of attacking the paraffin hydrocarbons and for the sake of convenience concentrated sulphuric acid was used.

It seems advisable, at this point, to call attention to the fact that the power of ordinary concentrated sulphuric acid to remove benzene and homologous hydrocarbons has been generally overlooked. In order to determine the percentages of these hydrocarbons it is customary to shake the oils to be analyzed with concentrated sulphuric acid and then to nitrate the unaffected oil. It is assumed that the acid removes such substances as the unsaturated hydrocarbons and does not attack the aromatic hydrocarbons. Thus, P. Poni,[3] in determining the presence and percentage of aromatic hydrocarbons in Roumanian petroleum, collected fractions between 35° and 70° C., distilled under diminished pressure. These were purified by shaking with sulphuric acid, and each was nitrated with a mixture of 1 part

[1] Am. Chem. Jour., vol. 20, p. 202; vol. 21, p. 210.
[2] Jour. Chem. Soc., 1898, p. 928.
[3] Annales sci. Univ. Jassy, 1907, pp. 192-202. (Abstracted in Jour. Chem. Soc., vol. 92, 1907.)

of nitric acid (specific gravity, 1.52) and 2 parts sulphuric acid (specific gravity, 1.8). The recovered oils were assumed to be paraffins and naphthenes, while the proportions of benzene and unsaturated hydrocarbons were calculated from the nitro-products obtained. It is obvious from the results obtained in the present work that some of the benzene was removed in the process of purifying the fractions. The amount dissolved depended on the vigor of the shaking and its duration, as well as the strength of the sulphuric acid. It is highly probable, therefore, that Poni's percentage of benzene is too low.

In the study of the mixture of benzene and paraffin hydrocarbons 25 cubic centimeters of each fraction, or all there was when the amount was less, was shaken vigorously with three times the volume of concentrated sulphuric acid for 30 minutes. The amount unabsorbed was measured over the acid in a burette, after sufficient time had been allowed for most of the oil mechanically held in suspension to rise. The oil was then reshaken with a little more acid for 15 minutes and the volume again read. When the benzene was present in small quantities one shaking was sufficient; when larger amounts were present shaking was repeated.

The paraffin oil employed (specific gravity, 0.797) was shaken several times with fresh portions of concentrated sulphuric acid until the coloration of the acid disappeared, and only a slight diminution in volume occurred when a small sample of the oil was thoroughly shaken by machine for some time with the acid. The oil was then washed with water and sodium hydroxide and dried over calcium chloride. The specific gravity decreased to 0.792.

When this oil was mixed with benzene in various proportions and allowed to diffuse upward through fuller's earth the following results, arranged in series, were obtained:

Results of diffusion of benzene and paraffin hydrocarbons through fuller's earth.

Series 1, oil alone.

[Specific gravity, 0.792. Level of oil, 28 centimeters.]

Grade.	Volume of oil (cubic centimeters).	Specific gravity.	Viscosity.	Per cent of benzene.
A	11	0.789		(a)
B	17	.792		
C	60	.7912	0.0154	
D	100	.7915	.0140	
E	150	.7913	.0134	
F	139	.7915	.0134	
	477			
Original volume [b]	778			

[a] In this series the percentages of benzene are not given, because the paraffin oil alone was used.
[b] The original volumes of solution vary with each series, owing to the fact that more or less always remained behind in the reservoir below the level of the tin support. In series 1, 2, 3, and 4, 950 cubic centimeters was supplied to each reservoir; in the rest of the series each reservoir contained originally 1,000 cubic centimeters.

Results of diffusion of benzene and paraffin hydrocarbons through fuller's earth—Contd.

Series 2, 90 per cent oil (0.792), 10 per cent benzene (0.8775).

[Specific gravity, 0.7983. Level of oil, 22 centimeters.]

Grade.	Volume of oil (cubic centimeters).	Specific gravity.	Viscosity.	Per cent of benzene.
A	11	0.787	....	10.0
B	16	.7923	....	13.3
C	56	.7935	0.0131	11.6
D	109	.7943	.0123	14.8
E	145	.7957	.0120	14.4
F	245	.7955	.0116	14.8
	582			
Original volume	872			

Series 3, 80 per cent oil (0.792), 20 per cent benzene (0.8775).

[Specific gravity, 0.806. Level of oil, 25 centimeters.]

Grade.	Volume of oil (cubic centimeters).	Specific gravity.	Viscosity.	Per cent of benzene.
A	25	0.7948	0.0147	15.3
B	35	.7981	.0130	16
C	78	.8017	.0117	22.4
D	128	.8005	.0105	21.6
E	166	.801	.0107	22.4
F	146	.798	.0110	20.8
	576			
Original volume	892			

Series 4, 75 per cent oil (0.792), 25 per cent benzene (0.8775).

[Specific gravity, 0.810. Level of oil, 33 centimeters.]

Grade.	Volume of oil (cubic centimeters).	Specific gravity.	Viscosity.	Per cent of benzene.
A	16	0.800	(a)	22
B	35	.803	0.0129	23.3
C	74	.8077	.0126	24
D	128	.805	.0114	24
E	152	.8068	.0102	26
F	120	.8065	.0105	28
	525			
Original volume	655			

Series 5, 75 per cent oil (0.794 [b]), 25 per cent benzene (0.8775).

[Specific gravity, 0.8115. Level of oil, 24 centimeters.]

Grade.	Volume of oil (cubic centimeters).	Specific gravity.	Viscosity.	Per cent of benzene.
A	25	0.7942	0.0123	14
B	28	.8048	.0104	21.2
C	70	.8105	.0094	31.2
D	140	.8100	.0094	27.6
E	172	.8100	.0094	32
F	144	.8093	.0095	27.6
	579			
Original volume	875			

[a] The viscosities of grades A and B in a few of the tables are not given, because in these series, the first made, the decision to determine the viscosities was reached only after the fractions had been treated with acid. As A and B were small in amount, all the oil was used in this treatment.

[b] As the quantity of oil of specific gravity 0.792 was not sufficient for all the series, a second quantity with the specific gravity 0.794 was prepared. This oil was used in series 5, 8, 9, and 10.

Results of diffusion of benzene and paraffin hydrocarbons through fuller's earth—Contd.

Series 6, 75 per cent oil (0.792), 25 per cent benzene (0.8775).

[Specific gravity, 0.8083. Level of oil, 27 centimeters.]

Grade.	Volume of oil (cubic centimeters).	Specific gravity.	Viscosity.	Per cent of benzene.
A	22	0.7995	0.0106	17.5
B	32	.8055	.0099	24.4
C	82	.8052	.0100	24
D	155	.8085	.0093	28.8
E	190	.8085	.0093	31.2
F	93	.8063	.0096	28.8
	574			
Original volume	923			

Series 7, 59.5 per cent oil (0.792), 40.5 per cent benzene (0.8775).

[Specific gravity, 0.8223. Level of oil, 9 centimeters.]

A	[a] 9	....	....	....
B	15	0.8069	....	14
C	48	.816	0.0103	22.4
D	96	.8182	.0086	31.2
E	160	.820	.0082	31.6
F	255	.8185	.0083	29.6
	583			
Original volume	922			

Series 8, 50 per cent oil (0.794), 50 per cent benzene (0.8775).

[Specific gravity, 0.8295. Level of oil, 17 centimeters.]

A	22	0.8122	....	24.5
B	32	.819	....	28.4
C	78	.8287	0.0077	44.8
D	111	.8275	.0077	47.6
E	155	.827	.0077	39.2
F	192	.8256	.0079	36.4
	590			
Original volume	960			

Series 9, 50 per cent oil (0.794), 50 per cent benzene (0.8775).

[Specific gravity, 0.8315. Level of oil, 18 centimeters.]

A	18	0.816	0.0091	26
B	24	.8210	.0085	34.5
C	76	.8275	.0078	47.6
D	136	.8283	.0077	50
E	174	.8293	.0076	49.2
F	144	.8277	.0078	40
	572			
Original volume	923			

Series 10, 50 per cent oil (0.794), 50 per cent benzene (0.8775).

[Specific gravity, 0.8295. Level of oil, 16 centimeters.]

A	31	0.8135	0.0097	31.6
B	45	.8251	.0081	43.6
C	85	.8290	.0076	46.4
D	140	.8280	.0077	47.6
E	175	.8285	.0076	49.6
F	137	.8272	.0076	50
	613			
Original volume	972			

[a] In series 7 the volume of grade A recovered was so small that no measurements could be made.

Results of diffusion of benzene and paraffin hydrocarbons through fuller's earth—Contd.

Series 11, 75 per cent crude oil (0.810), 25 per cent benzene (0.8775).

[Specific gravity, 0.8312. Level of oil, 18 centimeters.]

Grade.	Volume of oil (cubic centimeters).	Specific gravity.	Viscosity.	Per cent of benzene.
A	12	0.8255	0.0445	(a)
B	22	.8268	.0423	....
C	52	.8280	.0300	....
D	76	.8290	.0298	....
E	140	.8300	.0263	....
F	186	.8320	.0276	....
	488			
Original volume	890			

Series 12, benzene alone.

[Specific gravity, 0.8775. Level of oil, 33 centimeters.]

A	16	0.8765	....	....
B	15	.877	....	....
C	68	.878	0.0066	....
D	128	.8778	.0066	....
E	157	.8775	.0066	....
F	89	.8771	.0066	....
	473			
Original volume	888			

[a] The percentages of benzene in series 11, in which crude oil was employed, are not recorded, because, owing to the formation of heavy black emulsions, the loss in volume could not be determined with any degree of accuracy.

The results tabulated for series 2 to 10 are expressed diagrammatically in the curves shown in figures 2 to 6. The ordinates represent the different grades of oil, and the abscissas the percentages of benzene and the specific gravities. The curves in figure 7 represent as a whole the results of the experimental work on the diffusion of benzene in solution through fuller's earth. The ordinates of these curves represent the percentages of benzene, and the abscissas the various mixtures of benzene and oil that were allowed to diffuse through the earth.

An examination of these shows conclusively that benzene tends to collect in the lower portions of the tube. The specific gravities and viscosities confirm the results obtained by determining the percentages of benzene present by removing the benzene with concentrated sulphuric acid. The specific gravities of grades F to C run very close together and are all much greater than those of grades A and B. As benzene possesses a high specific gravity—in this work the specimen had a specific gravity of 0.8775—the larger values for the lower grades indicate the presence of larger amounts of benzene. The specific gravity of the paraffin oil was only 0.792, showing that the higher specific gravities were due to larger percentages of ber zene. Moreover, as the viscosity of the benzene used was 0.0066 and that of the paraffin oil about 0.0150, the viscosities of the fractions containing higher percentages of benzene ought to be much smaller than those of the fractions containing less benzene. The results show that the viscosities of grades F to C are much smaller than those of A and B.

It will be observed that the maximum in specific gravity is not at F, as may be expected in the fractionation of the crude oil, but

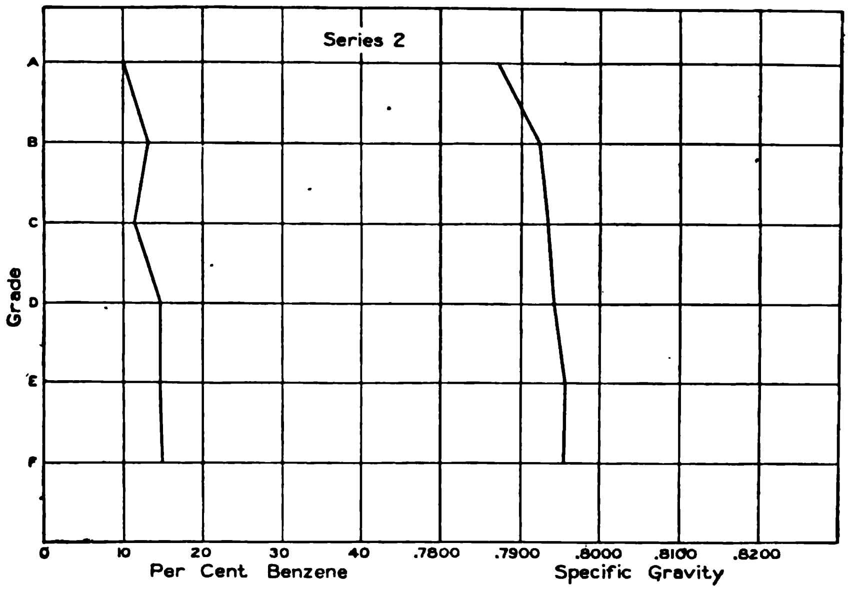

FIGURE 2.—Curve showing results of diffusion of benzene and paraffin oil through fuller's earth, series 2.

between C and D. Between B and C there is a marked decrease. This sudden break is found also in the viscosities and in the percentages of benzene. While the sharp breaks in the curves represent the marked change in the proportion of benzene and the height to which it rises in the tube, no satisfactory explanation has yet been obtained as to why it should occur at these points. This action will be studied more carefully later.

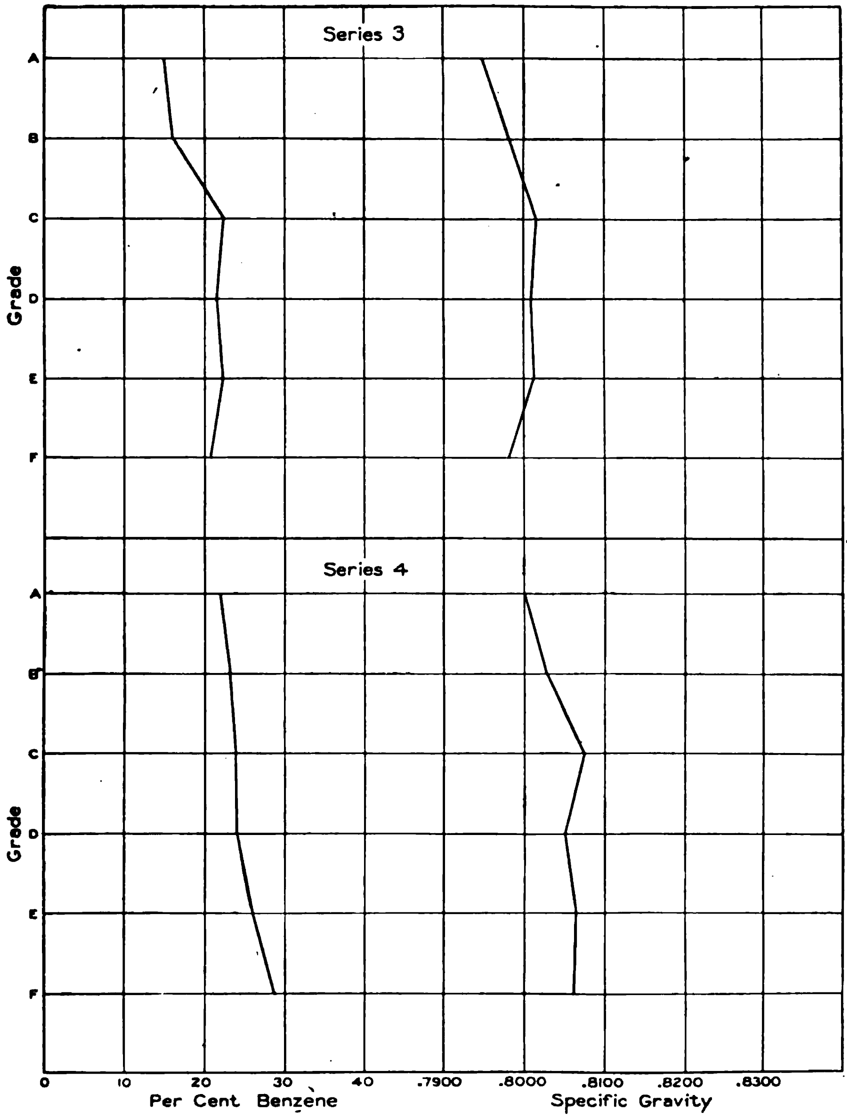

FIGURE 3.—Curves showing results of diffusion of benzene and paraffin oil through fuller's earth, series 3 and 4.

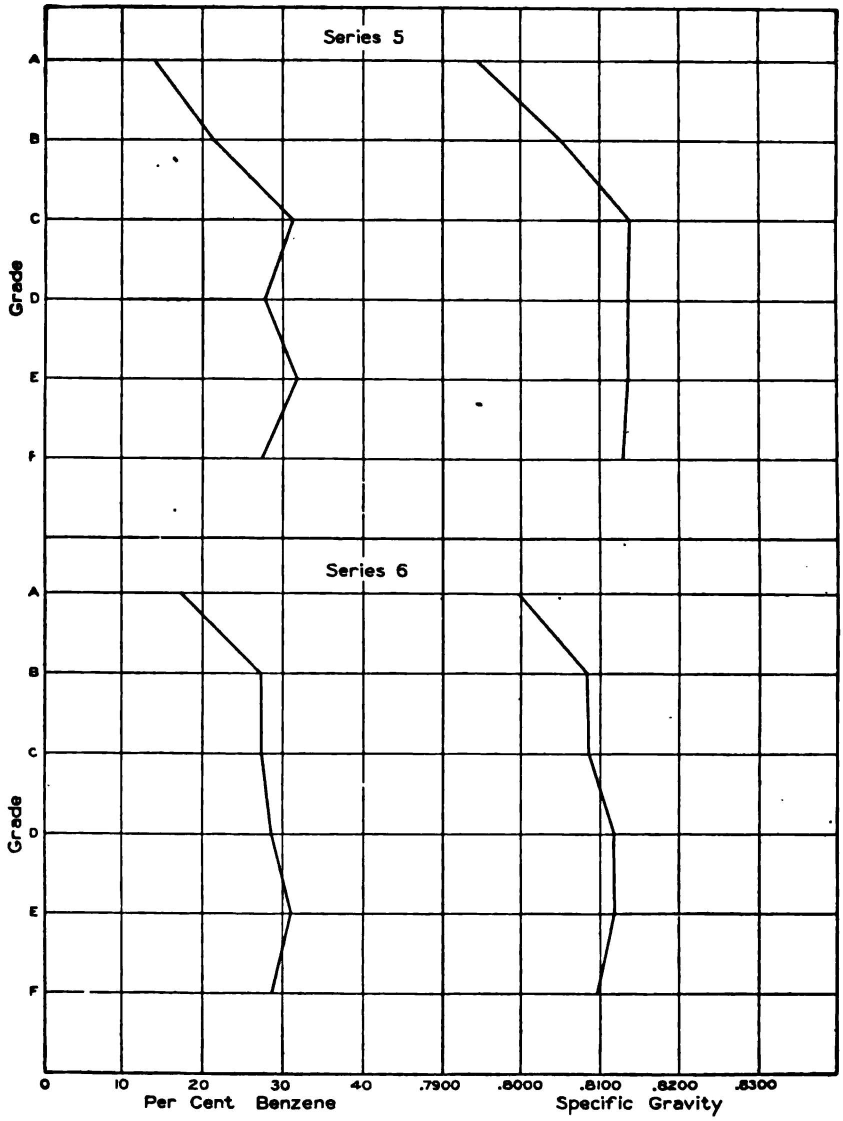

FIGURE 4.—Curves showing results of diffusion of benzene and paraffin oil through fuller's earth, series 5 and 6.

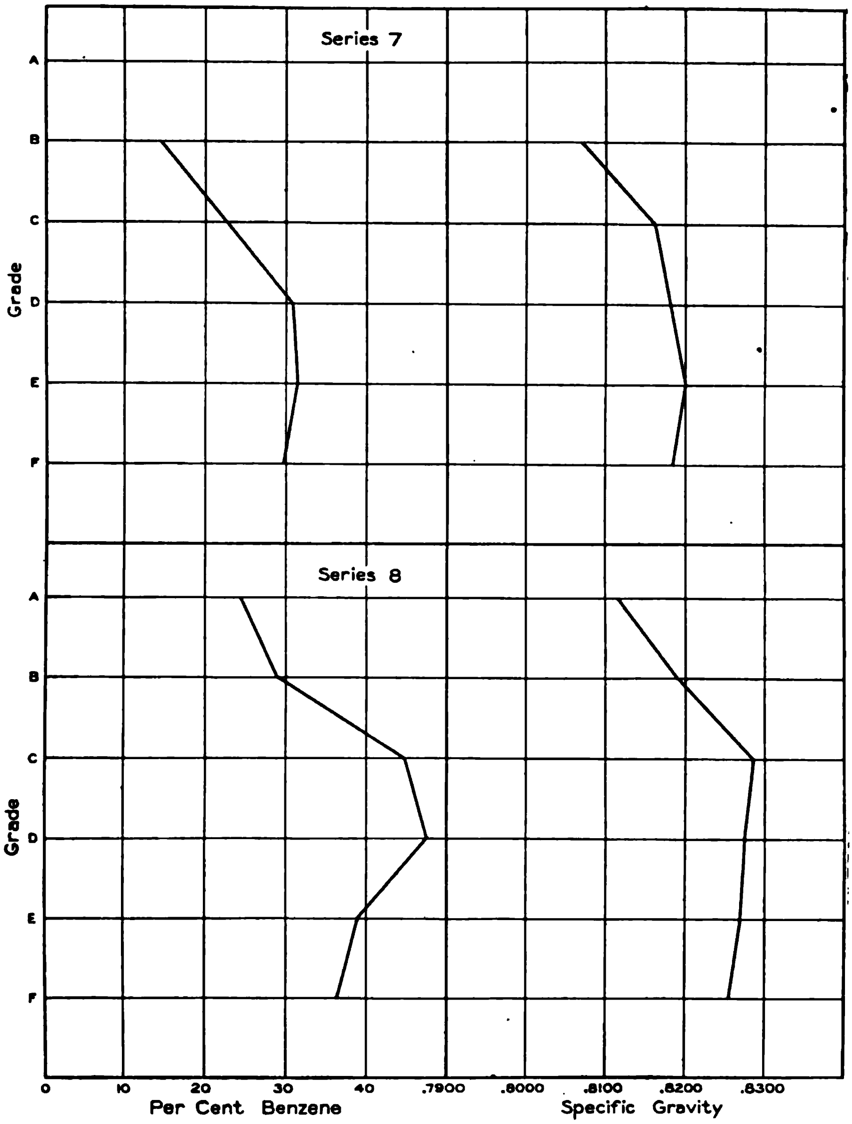

FIGURE 5.—Curves showing results of diffusion of benzene and paraffin oil through fuller's earth, series 7 and 8.

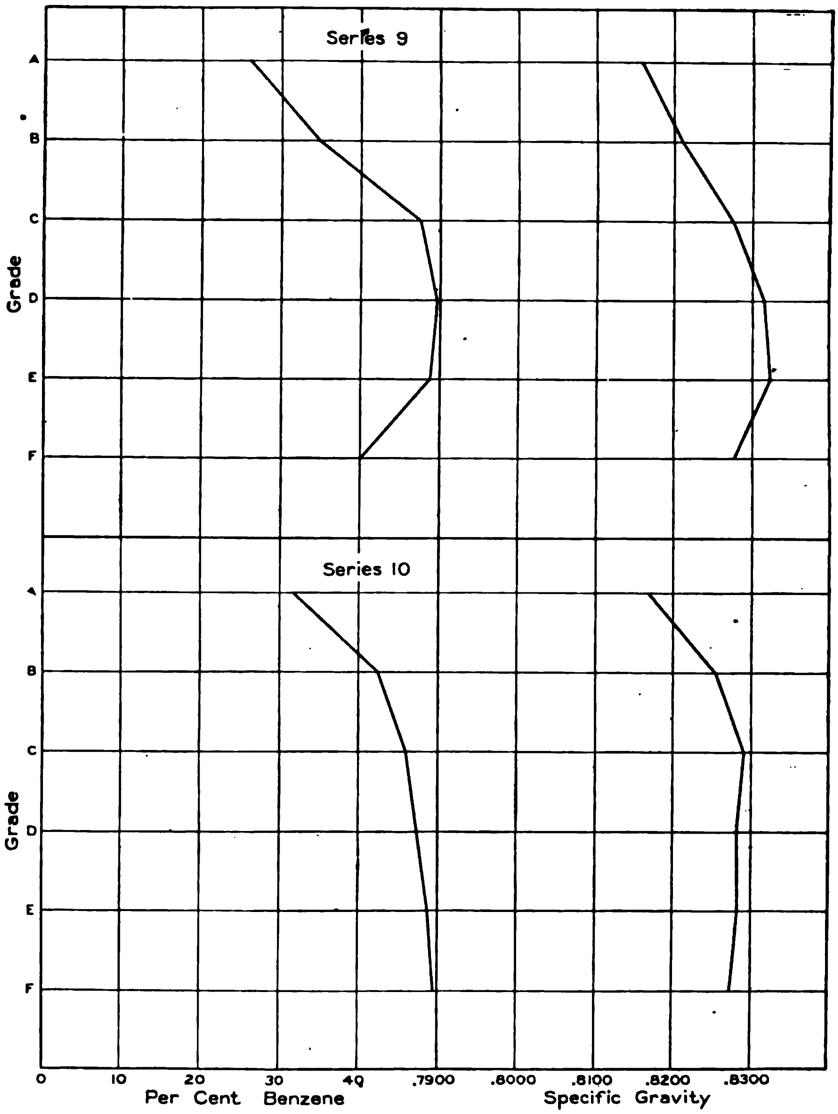

FIGURE 6.—Curves showing results of diffusion of benzene and paraffin oil through fuller's earth, series 9 and 10.

In order to determine the degree of exactness of the percentages of benzene obtained, known amounts of benzene were added to the

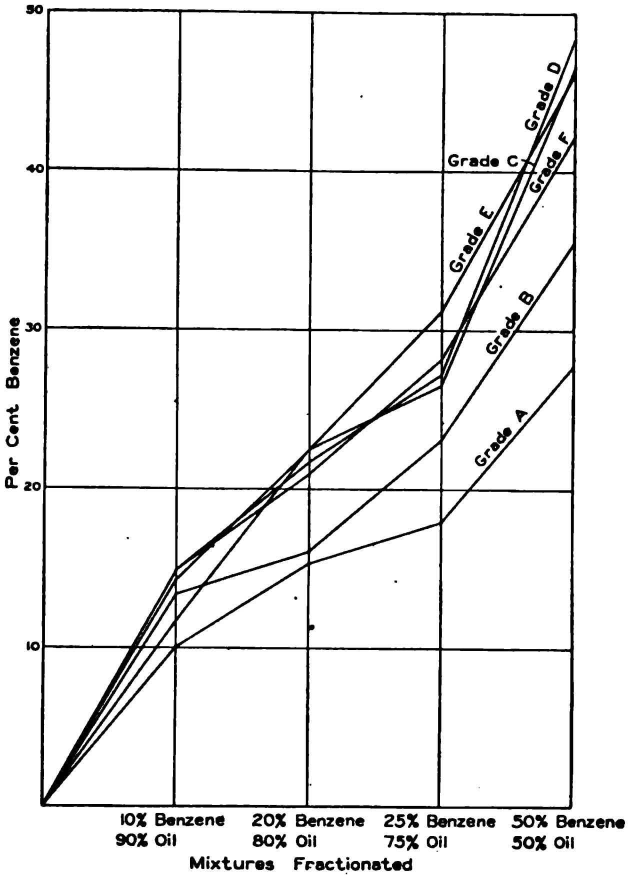

FIGURE 7.—Curves showing results of diffusion of benzene and paraffin oil through fuller's earth.

oil until the specific gravity corresponded closely to that obtained by fractionation.

The amount of benzene thus added and the amount actually removed by the acid agree very closely, as the following results show:

Results of tests to determine accuracy of benzene percentages.

Benzene in 25 cubic centimeters of mixture.		Benzene found in series 8.	
Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.
7.3	0.8143	Grade A, 7.9	0.8135
9.4	.8213	Grade B, 10.9	.8251
11.1	.8274	Grade F, 12.5	.8272
11.3	.8287	Grade E, 12.4	.8287
11.9	.8293	Grade C, 11.6	.8290

The variations in the specific gravities of the prepared mixtures and those of grades A to F are due to the fact that in the latter some fractionation had taken place in the paraffin oils, while in the mixtures the same paraffin oil was used each time. The paraffins found in grades A to F, therefore, exhibited slight gradations not common to the unfractionated paraffin oil used in preparing the mixtures.

FRACTIONATION OF PETROLEUM.

FIRST FRACTIONATION—CRUDE PETROLEUM.

The petroleum employed for the fractionation was an oil obtained by the United States Geological Survey from the E. E. Newlin farm, 2½ miles west of Robinson, Crawford County, Ill. The specific gravity of the oil was 0.8375 at 20° C.; its color was dark brown.

The fractionation of the oil was effected by upward diffusion through tubes packed with fuller's earth. In order to shorten the time required for the oil to diffuse by capillarity to the upper parts of the tube, the fine interstices and pores of the earth were evacuated by applying diminished pressure at the top of the tube. By this aid the time required for the oil to reach the top of a tube was reduced from several weeks to one or two days.

The apparatus employed is the same as that described on page 12.

The tin tubes, 5½ feet long and 1¼ inches in diameter, were packed as uniformly as possible by introducing definite amounts of earth and ramming solidly with rods tipped with rubber stoppers. The degree of compactness depended on the kind of oil to be used. For the crude oil about 1½ feet of the tube was filled at a time, and the earth packed as firmly as possible; for the lighter oils, 1 foot of the tube was filled at a time; for the oils heavier than the crude, between 2 and 3 feet of the tube was filled at one time.

The tubes were then placed individually in reservoirs containing 950 cubic centimeters of the crude oil, after which diminished pressure was applied at the top of the tubes. The oil rose rapidly at first, then diffused more and more slowly as it approached the tops of the tubes. When the oil in the reservoirs was completely exhausted the tubes were disconnected from the branced glass tube (see fig. 1, p. 13), and the oil-laden earth was shaken into two breakable cylinders. The following divisions of the earth were made: Fraction A, the first 10 centimeters measured downward from the level to which the oil had ascended; fraction B, the next 15 centimeters; C, 20 centimeters; D, 30 centimeters; E, 35 centimeters; and F, the remainder to the bottom of the tube. In the first fractionation up to lot 28, fraction F was discarded; from lot 28 to the end of the first fractionation, E and F were collected together.

After the earth was thus divided the several portions were placed in separate receptacles and treated with water. After each addition of water each portion was thoroughly mixed with it. The earth, when the oil first appeared, was granular; as more water was added, liberating more oil, the earth became muddy, and when as much oil as possible had been expelled by the water, the earth had the consistency of glue.

The portions of oil liberated by successive additions of water were collected separately. As Gilpin and Cram [1] pointed out, the oil that is first expelled, if not very small in volume as compared with the succeeding portions, possesses a lower specific gravity than the oil liberated by further additions of water; the latter in turn is lighter than the next succeeding oil. The oil that is liberated last, therefore, possesses a higher specific gravity than any of the portions preceding it. Sometimes, however, the specific gravity remains constant after the second or third extraction. This fractionation by means of water was combined with the fractionation effected by the fuller's earth. In the tables that follow A^1 represents the oil first liberated, A^2 the oil next liberated, etc. In the lower fractions (C, D, and E), three and sometimes four extractions were made before all the oil that could possibly be liberated by water was recovered.

The specific gravity of the oils was determined by means of the Mohr-Westphal balance. As mentioned before, the fourth decimal is not to be considered as rigidly accurate, but it gives a closer approximation to the truth than if it were entirely discarded. The temperature at which the specific gravity was measured was exactly 20° C.

Results of first fractionation.

	1		2		3			
Number of tubes	15		5		10			
Hours required [a]	18, 14 tubes; 23, 1 tube.		16		17, 8 tubes.		45, 2 tubes.	
Fraction.	Specific gravity.	Cubic centimeters [b]	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A^1	0.8250	312	0.8285	73	0.8223	138	0.8233	50
A^2	.8287	90	.8310	59	.8270	54	....	....
B^1	.8367	485	.8370	218	.8372	258	.8405	130
B^2	.8392	250	.8408	78	.8400	200	....	....
C^1	.8413	828	.8440	272	.8442	290	.8505	120
C^2	.8460	228	.8442	136	.8455	235	.8535	65
C^3	.8488	126	....	....	.8480	148	....	....
D^1	.8470	1,014	.8430	313	.8488	538	.8546	235
D^2	.8495	375	.8464	150	.8500	295	.8619	30
D^3	.8514	200	.8500	112	.8540	115	....	....
D^4	.8555	172	....	....	....	....	....	....
E^1	.8527	720	.8475	285	.8537	380	.8615	172
E^1	.8540	430	.8509	135	.8550	245	....	....
E^3	.8570	400	.8540	118	.8570	170	....	....

[a] Chapman pump was run day and night. Manometer indicated pressures ranging from 30 to 80 millimeters.
[b] In lots 1 to 5, 1,000 cubic centimeters of crude oil was supplied to each tube.

[1] Am. Chem. Jour., vol. 40, 1908.

Results of first fractionation—Continued.

	4		5		6			
Number of tubes	10		8		10[a]			
Hours required	16		17, 7 tubes; 24, 1 tube.		17, 1 tube;[b] 40, 3 tubes; 96, 1 tube.		17, 3 tubes; 40, 1 tube; 150, 1 tube.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A^1	0.8295	170	0.8313	130	0.8320	[c]72	0.8287	[c]85
A^2	.8315	100	.8357	56	.8352	22		
B^1	.8375	327	.8392	358	.8405	184	.8390	134
B^2	.8413	250	.8453	92	.8451	124	.8485	35
C^1	.8418	505	.8419	425	.8443	270	.8441	218
C^2	.8442	223	.8439	138	.8495	147	.8507	67
C^3	.8495	74	.8465	130				
D^1	.8449	495	.8454	640	.8483	368	.8450	302
D^2	.8455	328	.8500	167	.8517	210	.8490	132
D^3	.8490	260	.8509	195				
E^1	.8500	545	.8495	575	.8500	360	.8537	215
E^2	.8510	295	.8513	185	.8569	185	.8564	174
E^3	.8567	170	.8555	130				

	7				8		9	
Number of tubes	9				10		10	
Hours required	20, 7 tubes.		20, 1 tube; 24, 1 tube.		19, 8 tubes; 22, 2 tubes.		24, 2 tubes; 40, 8 tubes.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A^1	0.8325	66	0.8175	45	0.8364	88	0.8215	145
A^2	.8356	30			.8365	64	.8234	90
B^1	.8395	164	.8333	110	.8400	215	.8330	397
B^2	.8418	140			.8420	240	.8350	155
B^3							.8400	87
C^1	.8408	475	.8417	132	.8445	368	.8415	350
C^2	.8468	123	.8500	22	.8467	225	.8436	255
C^3					.8495	82	.8480	[d]160
D^1	.8449	500	.8468	110	.8465	460	.8485	507
D^2	.8487	270	.8498	106	.8478	260	.8495	280
D^3					.8500	260	.8545	247
E^1	.8500	483	.8533	228	.8490	450	.8548	313
E^2	.8524	318			.8495	354	.8550	275
E^3					.8521	233	.8580	375

[a] Beginning with lot 6, 950 cubic centimeters of crude oil was supplied to each tube.
[b] The pressure in the tubes was diminished intermittently.
[c] See page 14.
[d] Several cubic centimeters of this fraction were mixed, accidentally, with fraction E^3.

Results of first fractionation—Continued.

	10		11		12		13	
Number of tubes	8		10		9		10	
Hours required	17		17		42		24, 8 tubes; 40, 2 tubes.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A1	0.8273	130	0.8258	215	0.8325	125	0.8323	122
A2	.8288	75	.8318	70	.8345	87	.8352	96
B1	.8395	220	.8370	340	.8430	235	.8438	245
B2	.8418	160	.8480	180	.8467	120	.8470	180
C1	.8423	240	.8422	488	.8470	278	.8464	317
C2	.8440	195	.8450	205	.8487	288	.8505	235
C3	.8500	150	....	....	....	....	....	....
D1	.8460	410	.8465	565	.8495	452	.8500	312
D2	.8475	210	.8490	310	.8522	305	.8492	375
D3	.8500	348	.8530	187	....	....	.8518	150
E1	.8532	320	.8510	297	.8505	475	.8505	450
E2	.8535	282	.8520	405	.8533	490	.8489	395
E3	.8550	215	.8533	155	....	....	.8518	180

	14		15				16	
Number of tubes	5		6				15	
Hours required	24 [a]		26, 3 tubes.		26, 3 tubes.		40, 11 tubes; 64, 4 tubes.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A1	0.8355	132	0.8381	60	0.8305	73	0.8370	200
A2	....	....	....	....	....	....	.8357	108
B1	.8470	236	.8487	94	.8452	143	.8449	490
B2	....	....	....	....	....	....	.8445	226
C1	.8565	98	.8430	110	.8465	138	.8475	635
C2	.8560	150	.8480	57	.8509	88	.8509	235
C3	....	....	....	....	....	....	.8562	90
D1	.8523	170	.8475	212	.8505	158	.8540	825
D2	.8550	205	.8517	104	.8522	178	.8530	495
D3	....	....	....	....	....	....	.8575	150
E1	.8540	150	.8467	184	.8561	192	.8538	775
E2	.8532	325	.8502	152	.8585	140	.8562	620
E3	....	....	....	....	....	....	.8595	205

[a] When the pressure in the tubes was diminished the oil rose rapidly, and in a short time the reservoirs were nearly two-thirds exhausted. The pump was stopped and the remainder of the oil was allowed to diffuse during the night under normal pressure.

Results of first fractionation—Continued.

	17		18		19		20	
Number of tubes	9		8		10		10	
Hours required	40		24, 5 tubes; 48, 2 tubes; 64, 1 tube.		40, 8 tubes; 64, 2 tubes.		20, 6 tubes; 30, 4 tubes.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A	0.8258	225	0.8322	112	0.8320	146	0.8281	236
B	.8432	452	.8435	335	.8438	385	.8413	518
C[1]	.8480	450	.8495	250	.8480	300	.8450	350
C[2]	.8488	168	.8500	250	.8472	315	.8495	300
D[1]	.8530	520	.8530	320	.8509	422	.8508	325
D[2]	.8550	350	.8540	350	.8536	355	.8538	460
E[1]	.8585	385	.8547	[a] 90	.8492	580	.8513	445
E[2]	.8598	460	.8526	640	.8560	415	.8540	550

	21		22		23		24	
Number of tubes	10		10		10		10	
Hours required [b]	24, 6 tubes; 40, 2 tubes; 64, 2 tubes.		40, 6 tubes; 64, 4 tubes.		48, 5 tubes; 72, 5 tubes.		40, 4 tubes; 64, 6 tubes.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A	0.8275	245	0.8281	210	0.8241	330	0.8250	287
B	.8410	615	.8405	508	.8395	615	.8408	535
C[1]	.8452	520	.8459	265	.8448	420	.8463	475
C[2]	.8488	226	.8472	410	.8470	305	.8505	186
D[1]	.8512	533	.8505	435	.8533	400	.8540	525
D[2]	.8535	415	.8523	450	.8541	465	.8540	360
E[1]	.8557	375	.8615	385	.8650	305	.8623	393
E[2]	.8625	282	.8585	365	.8624	350	.8645	335

[a] This irregularity—that is, the liberation of oil with a specific gravity higher than those of the oils immediately following—is observed when an amount of water is added sufficient to replace a very small amount of oil for the first fraction.

[b] Pressure in the tubes was diminished intermittently.

Results of first fractionation—Continued.

	25		26		27		28	
Number of tubes	9		10		10		10	
Hours required [a]	48, 8 tubes; 72, 1 tube.		17, 2 tubes; 24, 4 tubes; 41, 4 tubes.		17, 4 tubes; 29, 6 tubes.		24, 7 tubes; 28, 3 tubes.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A	0.8270	225	0.8284	315	0.8312	230	0.8333	240
B	.8425	410	.8422	550	.8440	370	.8440	410
C¹	.8495	[b] 75	.8473	520	.8460	400	.8458	415
C²	.8492	250	.8508	178	.8478	232	.8500	177
D¹	.8509	320	.8515	600	.8482	435	.8470	387
D²	.8510	480	.8540	230	.8500	420	.8498	400
E¹	.8556	335	.8559	490	.8520	465	.8492	[c] 690
E²	.8570	395	.8586	135	.8565	335	.8505	680

	29		30		31		32	
Number of tubes	10		15		10		15	
Hours required [a]	18, 5 tubes; 40, 5 tubes.		20, 7 tubes; 41, 6 tubes; 63, 2 tubes.		44, 4 tubes; 89, 6 tubes.		40, 7 tubes; 89, 4 tubes; 103, 4 tubes.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A	0.8262	300	0.8348	335	0.8292	245	0.8270	445
B	.8395	505	.8468	630	.8439	576	.8423	726
C¹	.8463	390	.8490	560	.8495	465	.8500	730
C²	.8488	270	.8505	277	.8523	205	.8500	220
D¹	.8520	510	.8485	750	.8517	670	.8645	750
D²	.8543	290	.8502	540	.8552	210	.8543	540
EF¹	.8550	417	.8520	1,125	.8555	805	.8580	870
EF²	.8559	645	.8528	880	.8610	360	.8598	910
		3,327		5,097		3,536		5,191

[a] Pressure in the tubes was diminished intermittently.
[b] Some oil of this fraction was lost.
[c] Beginning with lot 28, fractions E and F were collected together.

Results of first fractionation—Continued.

	33		34		35	
Number of tubes	10		10		9	
Hours required[a]	41, 4 tubes; 65, 4 tubes; 89, 2 tubes.		44, 6 tubes; 68, 4 tubes.		48, 6 tubes; 72, 3 tubes.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A	0.8330	290	0.8355	320	0.8380	235
B^1	.8440	365	.8475	525	.8460	452
B^2	.8462	165	....	....	....	....
C^1	.8502	500	.8508	470	.8508	345
C^2	.8540	160	.8543	190	.8525	245
D^1	.8555	655	.8575	530	.8549	580
D^2	.8562	250	.8585	325	.8573	335
EF^1	.8575	735	.8535	895	.8557	645
EF^2	.8585	480	.8555	405	.8570	492
		3,600		3,660		3,329

[a] Pressure in the tubes was diminished intermittently.

Specific gravity.—The range of the specific gravity extended from 0.8175, the value of fraction A^1 of lot 7, to 0.8650, the value of fraction E^1 of lot 13. The specific gravity of the crude oil itself was 0.8375. The range of the specific gravities of the individual lots averaged from 0.820 to 0.860. The specific gravity decreases gradually from E to B, but in most of the lots the decrease between B and A is much greater than between any two consecutive lower fractions. This marked change was also observed in the study of the diffusion of benzene in solution. A detailed investigation of the cause will be undertaken in the near future.

Color.—The color of the fractions obtained ranged from green to black. The lighter oils possessed a beautiful green fluorescent color, which shaded gradually to brown, and then to the deep black of the heavier oils.

Odor.—The unpleasant odor of the crude petroleum disappeared almost entirely in the oils of fractions A and B; but the other fractions still possessed to a greater or less extent the odor of the natural oil.

Volume of oil retained by the fuller's earth.—The amount of oil retained by the earth averaged about 55 per cent of the amount supplied. In the first fractionation of the crude Pennsylvania oil, specific gravity 0.810, Gilpin and Cram found that approximately 40 per cent of the oil was retained by the earth. It is evident, therefore, that the amount of oil remaining in the earth depends chiefly on the character of the oil. The Pennsylvania petroleum contains a much smaller percentage of unsaturated hydrocarbons, sulphur, and asphaltic substances than the Illinois oil employed in this investigation. Inasmuch as the fuller's earth readily removes these substances in the process of fractionation, as will be shown later, the large percentage of Illinois oil retained by the earth is thus clearly explained. It is safe to conclude that if the heavy Texas or California oil was allowed to diffuse through fuller's earth, the amount of oil retained would exceed the amounts of either of the above-mentioned oils lost in the earth.

SECOND FRACTIONATION.

The products obtained from the first fractionation were united according to the following arrangement:

Specific gravity of oils united for second fractionation.

Lot.	Specific gravity.	Specific gravity of the oils united.
36	0.8293	0.8250-0.8350
37	.8390	.8350- .8400
38	.8433	.8400- .8450
39	.8433	.8400- .8450
40-43	.8490	.8450- .8500
44-50	.8543	.8500- .8600

The oils thus combined were subjected to chilling and filtration for the purpose of removing as much dissolved paraffin as possible. The procedure was as follows: The oils were first chilled at temperatures ranging from 0° to 10° C., and then filtered through plaited filter papers. When the oil ceased to drip from the funnel, the residue upon the filter paper was placed in a larger filter press, and the remaining oil was separated by pressure from the paraffin. The filter press was simple in construction. A piston, fitted closely in an iron cylinder, was gradually forced down upon the oil-laden paraffin, which rested upon a membrane of cotton duck, fastened between perforated tin supports. The retained oil was forced through the membrane and was collected from the outlet below. The lighter oils deposited very little paraffin; somewhat more paraffin was separated from the heavier ones. Owing to the high viscosity of the heavier oils, the filtration proceeded very slowly, and as too much time was consumed in this process, the paraffin of some of the oils of fraction E was not removed. A slight change in specific gravity occurred in the oils from which the paraffin was removed.

The final specific gravities of the united oils were as follows:

Final specific gravity of oils for second fractionation.

Lot.	Specific gravity.	Paraffin removed.
36	0.8305	Yes.
37	.8415	Yes.
38	.8433	No.
39	.8455	Yes.
40-42	.8515	Yes.
43	.8540	Yes.
44-48	.8543	No.
49-50	.8557	Yes.

When these oils were again allowed to diffuse upward through fuller's earth, the following fractionation was obtained:

Results of second fractionation.

	36		37		38		39	
Specific gravity	0.8305		0.8415		0.8433 [a]		0.8455 [b]	
Number of tubes	5		4		8		8	
Hours required [c]	44, 3 tubes; 48, 2 tubes.		51		48, 7 tubes; 64, 1 tube.		29, 4 tubes; 45, 3 tubes; 64, 1 tube.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A	0.8272	160	0.8292	135	0.8331	180	0.8290	255
B [1]	.8315	216	.8421	215	.8447	175	.8432	355
B [2]	.8331	58	.....	.....	.8455	210	.8458	110
C [1]	.8334	350	.8467	295	.8490	305	.8492	455
C [2]	.8355	85	.....	.....	.8505	175	.8513	150
D [1]	.8330	360	.8468	340	.8492	400	.8505	740
D [2]	.8339	320	.8485	152	.8509	295	.8527	275
EF [1]	.8347	720	.8480	535	.8508	710	.8546	1,166
EF [2]	.8356	320	.8489	215	.8518	355	.8560	350
		2,589		1,887		3,886		2,805

	40		41		42		43	
Specific gravity	0.8515		0.8515		0.8515		0.8540	
Number of tubes	9		5		5		4	
Hours required	48, 5 tubes; 72, 4 tubes.		40		69		10 days, 2 tubes; 17 days, 2 tubes.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A	0.8305	380	0.8316	235	0.8325	210	0.8435	65
B [1]	.8438	515	.8460	290	.8487	265	.8546	115
B [2]	.8453	155	.8480	65	.8515	54	.....	.....
C [1]	.8518	600	.8523	375	.8540	335	.8575	200
C [2]	.8539	170	.8540	100	.8567	56	.....	.....
D [1]	.8550	685	.8558	470	.8572	420	.8605	220
D [2]	.8560	330	.8571	110	.8582	175	.8640	50
EF [1]	.8605	780	.8620	580	.8640	675	.8650	225
EF [2]	.8620	600	.8622	320	.8650	200	.8615	78
		4,215		2,545		2,420		953

[a] Paraffin was removed from the oil.
[b] Paraffin was not removed from the oil.
[c] In this series, as well as those following, the pressure in the tubes was diminished intermittently.

Results of second fractionation—Continued.

	44		45		46		47	
Specific gravity [a]	0.8543		0.8543		0.8543		0.8543	
Number of tubes	3		5		5		5	
Hours required	48, 2 tubes; 96, 1 tube.		66		93		13 days.[b]	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A	0.8330	85	0.8362	170	0.8332	210	0.8340	145
B[1]	.8505	175	.8510	210	.8480	280	.8500	275
B[2]	....	....	.8522	80	.8505	50	....	....
C[1]	.8582	155	.8562	265	.8554	300	.8553	320
C[2]	.8605	65	.8585	50	.8567	95	.8576	50
D[1]	.8605	195	.8567	425	.8600	370	.8595	430
D[2]	.8620	120	.8580	100	.8613	120	.8618	70
EF[1]	.8672	240	.8659	615	.8666	610	.8665	330
EF[2]	.8680	175	.8670	150	.8680	130	.8670	215
		1,210		2,065		2,145		1,835

	48		49		50	
Specific gravity	0.8543 [a]		0.8557 [c]		0.8557 [c]	
Number of tubes	5		7		5	
Hours required	14 days.[d]		48		72, 4 tubes; 89, 1 tube.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A	0.8385	125	0.8341	255	0.8320	170
B[1]	.8530	275	.8505	395	.8485	230
B[2]	....	....	.8520	95	.8500	70
C[1]	.8568	320	.8560	380	.8565	300
C[2]	.8586	90	.8572	230	.8577	100
D[1]	.8610	325	.8620	500	.8609	480
D[2]	.8623	115	.8625	290	.8626	125
EF[1]	.8695	330	.8705	500	.8685	640
EF[2]	.8700	80	.8705	580	.8700	235
		1,660		3,225		2,350

[a] Paraffin was not removed from the oil.

[b] Owing to the weakness of the water pressure, the pressure in the tubes was only slightly diminished. The tubes were taken down before the reservoirs were completely exhausted. The distances to which the oil had risen were 35, 25, 30, 20, and 10 centimeters from the tops of the tubes.

[c] Paraffin was removed from the oil.

[d] Owing to the weakness of the water pressure, the pressure in the tubes was diminished but slightly during this time. The tubes were taken down before the reservoirs were completely exhausted. The distances to which the oil had risen were 50, 35, 30, 60, and 55 centimeters from the tops of the tubes.

Specific gravity.—The range of the specific gravities grows smaller as the oils to be fractionated become lighter and less complex. Thus, in lot 36, the range of specific gravity extends from 0.8272, the value of fraction A, to 0.8356, the value of EF², the difference between them being 0.0084. In lot 38, the mother oil, specific gravity 0.8433, yielded fractions whose specific gravities ranged from 0.8331 to 0.8518, amounting to a difference of 0.0187. This fact appears to be general throughout the various lots, and points to the gradual formations of mixtures which will pass through the earth unaltered, just as the fractionation by distillation tends to produce compounds with definite boiling points.

Color.—The color of the oils in this fractionation shaded from a very light yellow to greenish black.

Odor.—The odor of the crude petroleum vanished completely from the oils of this fractionation.

Volume of oil retained by the fuller's earth.—The oil retained by the earth in this fractionation amounted to approximately 50 per cent, a smaller percentage, as is naturally to be expected, than in the fractionation of the crude petroleum.

THIRD FRACTIONATION.

The following oils obtained from the second fractionation were united for the third fractionation.

Oils used for third fractionation.

Lot 51. [Specific gravity, 0.8316.]

Lot.	Fraction.	Specific gravity.	Cubic centimeter.
36	A	0.8272	160
39	A	.8290	255
37	A	.8292	135
40	A	.8305	380
36	B¹	.8315	216
41	A	.8316	235
50	A	.8320	170
42	A	.8325	210
44	A	.8330	85
36	B²	.8331	58
38	A	.8331	180
46	A	.8332	210
36	C¹	.8334	350
49	A	.8341	255
			2,899

Lot 52. [Specific gravity, 0.8343.]

Lot.	Fraction.	Specific gravity.	Cubic centimeter.
36	D¹	0.8330	360
36	D²	.8339	320
47	A	.8340	145
36	EF¹	.8347	720
36	EF²	.8356	320
36	C²	.8355	85
			1,950

Lot 53. [Specific gravity, 0.8433.]

Lot.	Fraction.	Specific gravity.	Cubic centimeter.
45	A	0.8362	170
48	A	.8385	125
37	B¹	.8421	215
39	B¹	.8432	355
40	B¹	.8438	515
38	B¹	.8447	175
40	B²	.8453	155
38	B²	.8455	210
39	B²	.8458	50
			1,970

Lot 54. [Specific gravity, 0.8473.]

Lot.	Fraction.	Specific gravity.	Cubic centimeter.
39	B²	0.8458	60
41	B¹	.8460	290
37	C¹	.8467	295
41	B²	.8480	65
50	B¹	.8485	230
42	B¹	.8487	265
39	C¹	.8492	455
38	C¹	.8490	305
			1,965

Oils used for third fractionation—Continued.

Lot 55.

[Specific gravity, 0.8485.]

Lot.	Fraction.	Specific gravity.	Cubic centimeter.
37	D^1	0.8468	340
37	D^2	.8485	152
37	EF^1	.8480	535
37	EF^2	.8489	215
38	D^1	.8492	400
47	B^1	.8500	275
			1,917

Lot 56.

[Specific gravity, 0.8508.]

Lot.	Fraction.	Specific gravity.	Cubic centimeter.
50	B^2	0.8500	70
49	B^1	.8505	395
44	B^1	.8505	175
46	B^2	.8505	50
38	C^2	.8505	175
45	B^1	.8510	210
39	C^2	.8513	180
42	B^2	.8515	54
40	C^1	.8518	600
			1,909

Lot 57.

[Specific gravity, 0.8509.]

Lot.	Fraction.	Specific gravity.	Cubic centimeter.
39	D^1	0.8505	740
38	EF^1	.8508	710
38	D^2	.8509	295
38	EF^2	.8518	355
			2,100

Lot 58.

[Specific gravity, 0.8558.]

Lot.	Fraction.	Specific gravity.	Cubic centimeter.
49	B^2	0.8520	95
45	B^2	.8522	80
41	C^1	.8523	375
48	B^1	.8530	275
40	C^2	.8539	170
42	C^1	.8540	335
41	C^2	.8540	100
47	C^1	.8553	320
46	C^1	.8554	300
49	C	.8560	380
45	C^1'	.8562	265
50	C^1	.8565	300
42	C^2	.8567	56
46	C^2	.8567	95
48	C^1	.8568	320
49	C^2	.8572	230
43	C^1	.8575	200
			3,896

Lot 59.

[Specific gravity, 0.8563.]

Lot.	Fraction.	Specific gravity.	Cubic centimeter.
39	EF^1	0.8546	1,166
40	D^1	.8550	685
41	D^1	.8558	470
39	EF^2	.8560	350
40	D^2	.8560	330
45	D^1	.8567	425
41	D^2	.8571	110
42	D^1	.8572	420
45	D^2	.8580	100
42	D^2	.8582	175
48	C^2	.8586	90
47	D^1	.8595	430
			4,750

Lot 60.

[Specific gravity, 0.8615.]

Lot.	Fraction.	Specific gravity.	Cubic centimeter.
46	D^1	0.8600	370
49	EF^1	.8605	780
43	D^1	.8605	220
44	D^1	.8605	195
50	D^1	.8609	480
48	D^1	.8610	325
46	D^2	.8613	120
47	D^2	.8618	70
40	EF^2	.8620	600
41	EF^1	.8620	580
44	D^2	.8620	120
49	D^1	.8620	500
41	EF^2	.8622	320
48	D^2	.8623	115
49	D^2	.8625	290
50	D^2	.8626	125
42	E^1	.8640	675
			5,880

Lot 61.

[Specific gravity, 0.8680.]

Lot.	Fraction.	Specific gravity.	Cubic centimeter.
42	EF^2	0.8650	200
43	EF^1	.8650	225
45	EF^1	.8659	615
47	EF^1	.8665	330
46	EF^1	.8666	610
47	EF^2	.8670	215
45	EF^2	.8670	150
44	EF^1	.8672	240
46	EF^2	.8680	130
44	EF^2	.8680	175
50	EF^1	.8685	640
48	EF^1	.8695	330
50	EF^2	.8700	235
49	EF^1	.8705	500
49	EF^2	.8705	580
			4,975

The oils thus united were fractionated by fuller's earth again, with the results given below.

Results of third fractionation.

	51		52		53		54	
Specific gravity	0.8316		0.8343		0.8433		0.8473	
Number of tubes	3[a]		2[a]		2		2	
Hours required	60		60		48		48	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A	0.8213	92	0.8219	65	0.8266	73	0.8303	66
B	.8303	185	.8333	143	.8431	115	.8488	115
C^1	.8337	165	.8375	190	.8464	175	.8518	175
C^2	.8345	90	....	....	....	....	....	....
D^1	.8353	210	.8388	188	.8468	145	.8523	189
D^2	.8356	170	.8393	90	.8474	115	.8528	105
E^1	.8366	385	.8403	175	.8473	202	.8530	245
E^2	....	....	.8411	92	.8488	73	.8548	60
F	.8373	190	.8431	88	.8496	170	.8548	145
		1,487		1,031		1,068		1,091

	55		56		57		58	
Specific gravity	0.8485		0.8508		0.8509		0.8558	
Number of tubes	2		2		2		4	
Hours required[b]	48, 1 tube; 72, 1 tube.		96		96		72, 3 tubes; 90, 1 tube.	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A	0.8283	58	0.8313	75	0.8336	55	0.8318	170
B	.8457	100	.8488	135	.8491	130	.8531	260
C^1	.8515	155	.8546	170	.8528	180	.8578	205
C^2	....	....	....	....	....	....	.8592	105
D^1	.8521	220	.8553	150	.8551	185	.8588	206
D^2	.8543	50	.8560	92	.8573	45	.8593	340
E^1	.8540	270	.8553	145	.8568	170	.8603	325
E^2	....	....	.8563	90	.8588	70	.8613	170
F	.8566	180	.8575	130	.8611	170	.8628	275
		1,033		987		1,005		2,055

[a] The tin tubes used in these lots were 1½ inches in diameter.
[b] The pressure in the tubes was diminished intermittently.

Results of third fractionation—Continued.

	59		60		61	
Specific gravity	0.8563		0.8615		0.8680	
Number of tubes	5		6		5	
Hours required	72		72		5 days. [a]	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters. [b]
A	0.8328	195	0.8343	195	0.8413	....
B	.8568	340	.8540	330	.8601	....
C^1	.8578	325	.8601	290	.8683	....
C^2	.8588	112	.8618	130	....	....
D^1	.8608	490	.8628	440	.8709	....
D^2	.8623	135	.8638	85	....	....
E^1	.8628	475	.8664	425	.8688	....
E^2	.8633	155	.8683	140	....	....
F	.8673	330	.8703	310	.8691	....
		2,557		2,345		....

[a] See below. [b] The volumes of these oils were not recorded.

Specific gravity.—The decrease in the range of specific gravity as the oils supplied become lighter was observed in this fractionation as in the preceding ones.

Color.—The lightest oils were almost colorless; the heavier oils were dark brown to green.

Odor.—Most of the oils possessed an agreeable odor.

Prolonged diffusion.—In lot 61 the time required for the oils to reach the tops of the tubes was five days. No fractionation, as is evident from an examination of the specific gravities, occurred in the lower parts of the tubes. The heavier oils of fractions D, E, and F were exceedingly viscous.

Volume of oil retained by the fuller's earth.—The volume of oil retained by the earth in this fractionation amounted to approximately 45 per cent. The increase in the yield of oil indicates, therefore, a process of purification, in which, as will be shown later, such compounds as the unsaturated hydrocarbons are removed.

FOURTH FRACTIONATION.

The following fractions obtained from the third fractionation were united for the fourth fractionation:

Oils used for fourth fractionation.

Lot 62.

[Specific gravity, 0.8298.]

Lot.	Fraction.	Specific gravity.	Cubic centimeters.
51	A	0.8213	92
52	A	.8219	65
53	A	.8266	73
55	A	.8283	66
54	A	.8303	58
51	B	.8303	185
56	A	.8313	75
58	A	.8318	170
59	A	.8328	195
			979

Lot 63.

[Specific gravity, 0.8343.]

Lot.	Fraction.	Specific gravity.	Cubic centimeters.
52	B	0.8333	143
57	A	.8336	55
51	C^1	.8337	185
60	A	.8343	195
51	C^2	.8345	90
51	D^1	.8353	210
51	D^2	.8356	170
			1,040

Lot 64.

[Specific gravity, 0.8368.]

Lot.	Fraction.	Specific gravity.	Cubic centimeters.
51	E^1	0.8366	388
51	F	.8372	190
52	C^1	.8375	190
52	D^1	.8388	188
			956

Lot 65.

[Specific gravity, 0.8430.]

Lot.	Fraction.	Specific gravity.	Cubic centimeters.
52	D^2	0.8393	90
52	E^1	.8403	175
52	E^2	.8411	92
53	B^1	.8431	115
52	F	.8431	88
55	B^1	.8457	100
53	C^1	.8464	175
53	D^1	.8468	145
			980

Lot 66.

[Specific gravity, 0.8483.]

Lot.	Fraction.	Specific gravity.	Cubic centimeters.
53	E^1	0.8473	202
53	D^2	.8474	115
54	B^1	.8488	115
56	B^1	.8488	135
53	E^2	.8488	73
59	B^1	.8508	330
			970

Lot 67.

[Specific gravity, 0.8513.]

Lot.	Fraction.	Specific gravity.	Cubic centimeters.
57	B^1	0.8491	130
59	B^1	.8508	10
55	C^1	.8515	155
54	C^1	.8518	175
55	D^1	.8521	220
58	B^1	.8531	260
			950

Lot 68.

[Specific gravity, 0.8533.]

Lot.	Fraction.	Specific gravity.	Cubic centimeters.
54	D^1	0.8523	180
54	D^2	.8528	105
57	C^1	.8528	180
54	E^1	.8530	245
60	B	.8540	330
			1,040

Lot 69.

[Specific gravity, 0.8556.]

Lot.	Fraction.	Specific gravity.	Cubic centimeters.
55	E^1	0.8540	270
55	D^2	.8543	50
56	C^1	.8546	170
54	E^2	.8548	60
54	F	.8548	145
57	D^1	.8551	185
56	D^1	.8553	150
56	E^1	.8553	145
56	D^2	.8560	92
56	E^2	.8563	90
55	F	.8566	180
57	E^1	.8568	170
57	D^2	.8573	45
56	F	.8575	130
			1,882

Oils used for fourth fractionation—Continued.

Lot 70. [Specific gravity, 0.8596.]				Lot 71. [Specific gravity, 0.8638.]			
Lot.	Fraction.	Specific gravity.	Cubic centimeters.	Lot.	Fraction.	Specific gravity.	Cubic centimeters.
58	C^1	0.8578	205	59	D^2	0.8623	135
59	C^1	.8578	325	60	D^1	.8628	440
58	D^1	.8588	205	59	E^1	.8628	475
59	C^2	.8588	112	58	F	.8628	375
57	E^2	.8588	70	60	D^2	.8638	85
58	C^2	.8592	105	59	E^2	.8633	155
58	D^2	.8593	340	60	E^1	.8664	425
60	C^1	.8601	290				1,990
58	E^1	.8603	325				
59	D^1	.8608	490				
57	F	.8611	170				
58	E^2	.8613	170				
60	C^2	.8618	130				
			2,937				

Results of fourth fractionation.

	62		63		64		65	
Specific gravity	0.8298		0.8343		0.8368		0.8430	
Number of tubes	1		1		1		1	
Hours required	72		72		90		48	
Fraction.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.
A	0.8243	32	0.8273	45	0.8297	41	0.8308	42
B	.8298	71	.8357	75	.8378	57	.8428	70
C	.8323	90	.8378	95	.8401	81	.8463	92
D	.8330	115	.8383	130	.8408	115	.8473	130
E	.8333	130	.8388	98	.8413	135	.8471	130
F	.8341	75	.8393	95	.8418	70	.8483	80
		513		538		499		544

Specific gravity.—As in the preceding fractionations, the decrease in the range of specific gravity as the mother oils became lighter was again observed in this fractionation. It was evident, moreover, that there was a constant forward accumulation toward definite and constant mixtures. The lighter oils of one lot were found to possess specific gravities closely approaching those of the heavier oils of the preceding lot.

Color.—The oils of fraction A were almost colorless; the color of the heavier oils ranged from green to light brown.

Odor.—All the oils of this fractionation possessed agreeable odors.

Volume of oil retained.—The volume of oil retained by the earth amounted to approximately 40 per cent.

Deposition of paraffin.—In fractions A and B of several of the lots a fine crystalline deposit separated out and collected upon the bottom of the bottles containing the oi[l]. When the oils were warmed, this deposit dissolved completely, showing it t[o be] paraffin.

CHEMICAL EXAMINATION OF FRACTIONATED OILS.

UNSATURATED HYDROCARBONS.

ACTION OF CONCENTRATED SULPHURIC ACID.

The percentage by volume of oil absorbed by concentrated sulphuric acid (specific gravity 1.84) was determined according to the following procedure. Ten cubic centimeters of the oil to be examined was measured into a glass-stoppered bottle, and 30 cubic centimeters of concentrated sulphuric acid was added. The mixture was thoroughly shaken by a machine for 30 minutes and then poured into a burette. After sufficient time had been allowed for any oil that might be mechanically absorbed in the acid to rise to the top, the volume of unabsorbed oil was read directly over the acid. Owing to the formation of heavy emulsions, no attempt was made to neutralize and wash the oil. The results of the analyses are given in the following table:

Oil absorbed by concentrated sulphuric acid, lot 51.

	Per cent by volume.
Fraction A	2.3
B	6.1
C^1	9.1
C^2	10.2
D^1	11.5
D^2	12.0
E	12.5
F	14.5

ACTION OF BROMINE.

The following method was employed for determining the amount of bromine absorbed by the oils. Between 0.5 and 0.9 gram of the oil to be examined was dissolved in 10 to 15 cubic centimeters of carbon tetrachloride. Five cubic centimeters of a standard solution of bromine in carbon tetrachloride was then introduced, and the solution allowed to remain, with occasional shaking, in a dark place for 30 minutes. Ten cubic centimeters of a 10 per cent solution of potassium iodide was then added, and the amount of iodine liberated was determined immediately by titrating with a standard solution of sodium thiosulphate. A few drops of a starch solution were introduced to mark accurately the end of the titration. The separate amounts of bromine absorbed by addition and substitution were not estimated. The amounts of bromine absorbed, expressed in the table below, are calculated on the basis of 100 grams of oil.

Bromine absorbed by oil.

First fractionation.

	Per cent.
Lot 32, fraction A	5.02
B	6.96
C	7.40
D	7.87
E	8.00
Crude oil	7.64

Second fractionation.

Lot 36, fraction A	4.74
B¹	5.40
B²	5.66
C¹	5.56
C²	6.18
D¹	6.81
D²	6.28
EF¹	6.49
EF²	7.18

Third fractionation.

Lot 51, fraction A	3.27
B	4.36
C	4.47
D	4.92
E	4.71
F	5.36

Fourth fractionation.

Lot 62, fraction A	2.86
E	3.73

These results demonstrate conclusively that the unsaturated hydrocarbons tend to collect in the lower sections of a layer of fuller's earth through which the oil is allowed to diffuse. The figures confirm the results obtained by Gilpin and Cram in their work on Pennsylvania petroleum. In their investigation distillation by heat was employed in order to obtain fractions that could be readily studied. In the work here reported the relative amounts of the unsaturated hydrocarbons in the oils were determined directly as they came from the earth.

The percentages by volume of oil absorbed by concentrated sulphuric acid represent only approximately the percentages of unsaturated hydrocarbons, for, as was shown previously, any benzene which may have been present in the oils was also removed by the concentrated acid. This fact rendered impossible a quantitative separation of the aromatic from the unsaturated hydrocarbons. As no other methods besides nitration and sulphonation, neither of which could be here employed, were available, no results as to the relative amounts of the aromatic hydrocarbons in the various fractions could be obtained.

It is evident from the results of the bromine determinations that as the fractionation proceeds the amounts of unsaturated hydrocarbons become smaller and smaller. A comparison of the amounts of bromine absorbed by fraction A of the first, second, third, and fourth fractionations is given below for the purpose of bringing out this point more clearly.

Bromine absorbed by fraction A.

	Per cent.
First fractionation	5.02
Second fractionation	4.74
Third fractionation	3.27
Fourth fractionation	2.86

SULPHUR COMPOUNDS.

The amount of sulphur in the oils was determined by the usual method of combustion. For these determinations the oils obtained from one tube of lot 6 were employed. The results are given in the following table:

Sulphur in oils of lot 6.

	Specific gravity.	Per cent of sulphur.
Fraction A	0.8195	0.04
B	.8362	.05
C	.8440	Lost.
D	.8510	.09
E	.8600	.16

The percentage of sulphur in fractions A, C, and E of lot 51 was also determined. The results were as follows:

Sulphur in oils of lot 51.

	Per cent.
Fraction A	0.003
C	.040
E	.006

These results show that the sulphur tends to collect in the oils in lower sections of the tube. As the fractionation proceeds the proportion of sulphur becomes smaller. The figures below indicate that as the oil is subjected to repeated filtrations the sulphur is gradually removed.

Sulphur remaining after first, second, and third fractionations.

	First.	Second.	Third.
Fraction A	0.04		0.003
C		0.08	.040
E	.16		.006

SELECTIVE ACTION OF FULLER'S EARTH.

When the earth from which as much oil as possible has been extracted by prolonged treatment with water is dried and digested with ether, oils of surprisingly high specific gravity and viscosity are obtained.

In the experiments undertaken to study the selective action of fuller's earth, the following method of procedure was adopted. The earth under examination was treated with water until no more oil appeared. This muddy earth, of the consistency of thin liquid paste, was spread upon porous plates and allowed to dry at room temperature. Several weeks usually elapsed before the earth became completely dry. It was then pulverized, and after being thoroughly soaked and shaken with ether, the mixture was allowed to remain undisturbed for 24 hours or more. The mixture was then filtered and the dissolved oil recovered by distilling off the ether from the filtrate. The residual earth was then digested with ether for some time by means of an electric stove that completely surrounded the flask. The oil thus extracted was added to the oil first obtained. In several cases the residual earth was treated further with ether in the Soxhlet extractor. The results of these extractions are given in the following table:

Oils extracted by ether.

Lot.	Fraction.	Specific gravity at 50° C.	Lot.	Fraction.	Specific gravity at 20° C.
7	A	0.8470	25	A^3	0.8391
8	A	.8502	25	B	.8489
18	A^1	.8419	51	A	.8368
18	A^2	.8400	51	B	.8473
19	A^1	.8495	51	C	.8491
19	A^2	.8495	51	D	.8568
19	A^3	.8600	51	E	.8518
25	A^1	.8363	51	F	.8553
25	A^2	.8381			

The specific gravity of none of the ether-extracted oils of the first and second fractionation, except those of lot 19, could be determined at 20° C. All were extremely viscous; those of lot 25 were so viscous at this temperature that they would not flow when the bottles containing them were inclined. The color of the oils ranged from brown to black. The ethereal solutions, however, of many of the oils were very light in color.

It is interesting to compare the specific gravities of the ether-extracted oils with those of the corresponding water-extracted oils. For this purpose, the oils extracted by water and by ether from the earth of lot 51 are chosen. In the following table the specific gravities of these oils at the same temperature (20° C.) are given.

Comparison of specific gravities.

	Ether-extracted oils.	Water-extracted oils.
Lot 51, fraction A	0.8363	0.8213
B	.8473	.8303
C	.8491	.8337
D	.8568	.8353
E	.8518	.8366
F	.8553	.8373

As the figures indicate, the specific gravities of ether-extracted oils are much higher than those of the corresponding water-extracted oils. The presence of such heavy and viscous oils in the upper sections of the tube can be explained only by assuming that they were carried to these heights in solution with the lighter oils and were then removed by the earth. As such viscous oils are totally unable to diffuse by capillarity to any appreciable extent, it is not probable that their transportation to the upper parts of the tube was effected by capillary diffusion.

CHEMICAL EXAMINATION OF THE OILS EXTRACTED BY ETHER.

UNSATURATED HYDROCARBONS.

ACTION OF CONCENTRATED SULPHURIC ACID.

The percentage by volume of oil absorbed by concentrated sulphuric acid (specific gravity 1.84) was determined according to the following procedure: Ten cubic centimeters of the oil to be examined was measured into a glass-stoppered bottle, and 30 cubic centimeters of concentrated sulphuric acid was added. The mixture was thoroughly shaken by a machine for 30 minutes and then poured into a burette. After sufficient time had been allowed for any oil that might be mechanically absorbed in the acid to rise to the top, the volume of unabsorbed oil was read directly over the acid. Owing to the formation of heavy emulsions, no attempt was made to neutralize and wash the oil. The oils selected for examination were those extracted by ether from the earth of lots 36 and 51. The results of the analyses are expressed in the following table:

Action of sulphuric acid on oils extracted by ether and by water.

[Per cent by volume absorbed.]

	Ether-extracted oils.	Water-extracted oils.
Lot 36, fraction A	24	3
B	37	10.4
Lot 51, fraction A	7	2.3
B	11.5	6.1
C	17	9.1
D	16.4	11.5
E	16.5	12.5
F	18	14.5

ACTION OF BROMINE.

The method employed for determining the amount of bromine absorbed by the oils was as follows: Between 0.5 and 0.9 gram of the oil to be examined was dissolved in 10 to 15 cubic centimeters of carbon tetrachloride. Five cubic centimeters of a standard solution of bromine in carbon tetrachloride was then introduced, and the solution allowed to remain, with occasional shaking, in a dark place for 30 minutes. Ten cubic centimeters of a 10 per cent solution of potassium iodide was then added, and the amount of iodine liberated was determined immediately by titrating with a standard solution of sodium thiosulphate. A few drops of a starch solution was introduced to mark accurately the end of the titration. The separate amounts of bromine absorbed by addition and substitution were not estimated.

The amounts of bromine absorbed, expressed in the following table, are calculated on the basis of 100 grams of oil. The values for the corresponding water-extracted oils are also given for comparison.

Bromine absorbed by oil extracted by ether and water.

	Ether-extracted oils.	Water-extracted oils.
	Per cent.	*Per cent.*
Lot 32, fraction A	5.30	5.02
B	7.39	6.96
Lot 36, fraction A	5.72	4.74
B	6.10	5.40
C	6.72	5.56
Lot 51, fraction A	3.27	3.27
B	4.45	4.36
C	6.27	5.03
D	6.09	4.92
E	5.98	4.71
F	5.20	5.36

As these results clearly demonstrate, one of the properties of fuller's earth is to retain the unsaturated hydrocarbons, thus exercising a selective action.

SULPHUR COMPOUNDS.

The sulphur in the oils obtained by extraction with ether was determined by the usual method of combustion. The results are given in the table below.

Sulphur in oils extracted by ether and water.

	Ether-extracted oils.	Water-extracted oils.
	Per cent.	*Per cent.*
Lot 51, fraction A	0.004	0.003
B	.011	
C	.050	.040
D	.060	
E	.080	
F	.080	[illegible]

The selective action of the earth, in regard to the sulphur compounds, is indicated by these results. This fact was also pointed out by Richardson and Wallace. It is very probable that the earth also retains largely the nitrogen compounds in the oil, and it may also remove to a greater or less extent the benzene hydrocarbons.

These results seem to furnish evidence in favor of the view that the Illinois oil at some time in its history diffused through porous media, which exercised a selective action upon it, removing a large part of the unsaturated and sulphur compounds and probably the benzene and nitrogen compounds.

SUMMARY.

When a solution of benzene and a paraffin oil is allowed to diffuse upward through a tube packed with fuller's earth, the benzene tends to collect in the lower sections and the paraffin oil in the upper sections of the tube.

When crude petroleum diffuses upward through a tube packed with fuller's earth a fractionation of the oil occurs. The oil that is displaced by water from the earth from the top of the tube possesses a lower specific gravity than the oil obtained from the earth at the bottom of the tube.

As the fractionation proceeds the range of specific gravity covered in succeeding fractionations becomes smaller, indicating a movement toward the production of mixtures which will finally pass through the earth unaltered.

In the fractionation of petroleum by capillary diffusion through fuller's earth the amounts of unsaturated hydrocarbons and sulphur compounds in the resulting fractions increase gradually from the lightest oils at the top to the heavier oils at the bottom of the tube.

Fuller's earth tends to retain the unsaturated hydrocarbons and sulphur compounds in petroleum, thus exercising a selective action upon the oil.

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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 476

RESULTS OF SPIRIT LEVELING IN OHIO

1909 AND 1910

R. B. MARSHALL, CHIEF GEOGRAPHER

WORK DONE IN COOPERATION WITH THE STATE OF OHIO

WASHINGTON
GOVERNMENT PRINTING OFFICE
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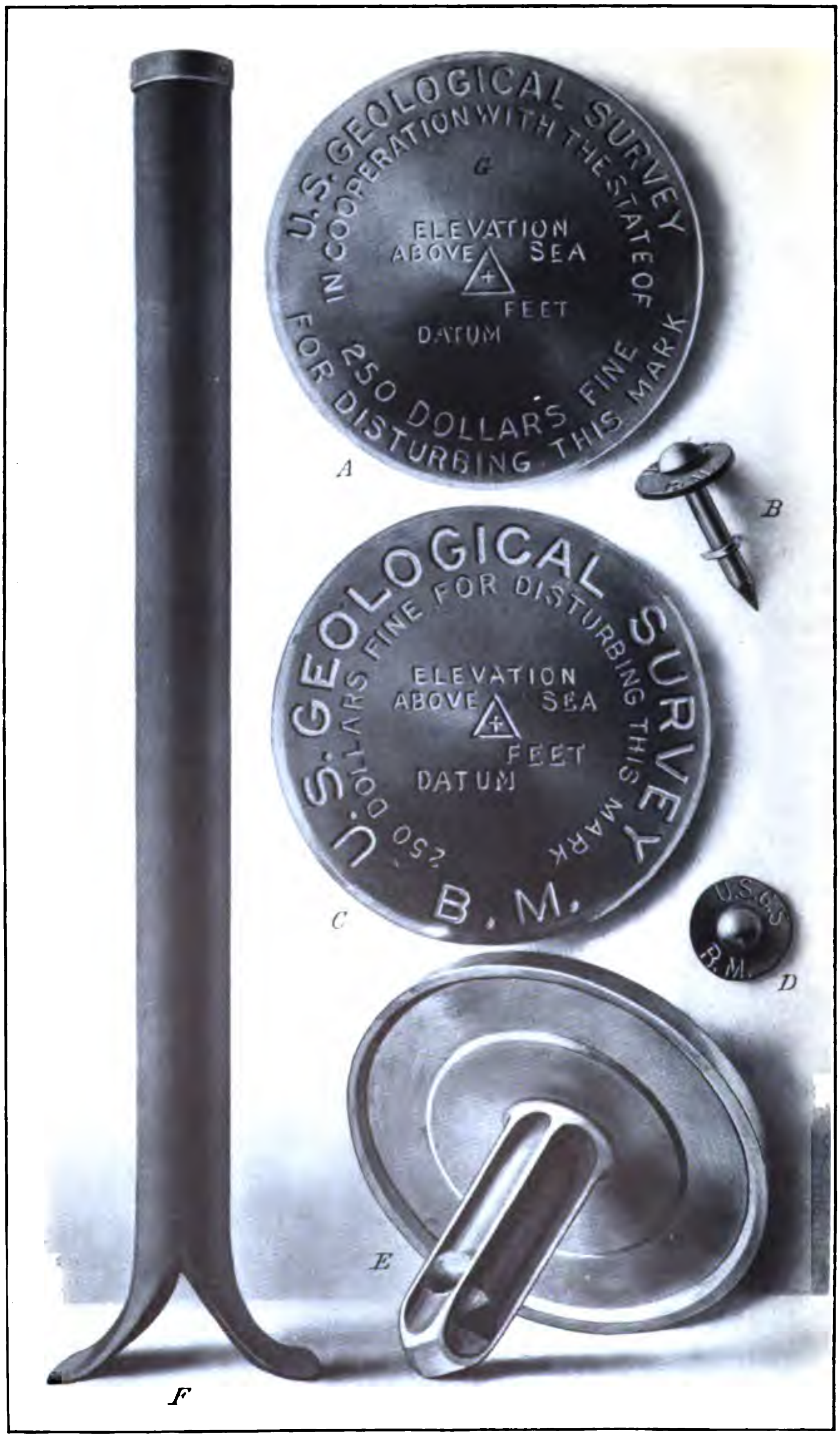
ILLUSTRATION.



GEOLOGICAL SURVEY BENCH MARKS.

A, Tablet used in cooperating States. The State name is inserted at *G*.
B and *D*, Copper temporary be[illegible] mark consisting of a nail and copper washer.
A, *C*, and *E*, Tablets for ston[illegible]tures.
F, Iron post used where ther[illegible]

RESULTS OF SPIRIT LEVELING IN OHIO, 1909 AND 1910.

R. B. Marshall, Chief Geographer.

INTRODUCTION.

Previous publication.—The following results of spirit leveling are supplemental to and accord with the elevations contained in Bulletin 411 and are in agreement with the 1907 adjustment of precise leveling. Corrections to Bulletin 411 should be noted as follows:

Page 29, Hiram; aluminum tablet in northwest corner of foundation of brick store building opposite Y. M. C. A.; the elevation of this mark has been changed and now is 1,269.617 feet above mean sea level.

Page 39, Zoar; bench mark is now 600 feet north of station, south side of track, in abutment of iron bridge 153–D over mill race, in coping stone; aluminum tablet stamped "893 STEUBENVILLE," elevation taken as 898.21 feet. The accuracy of this elevation is not known.

Page 55, Little Hocking; old bench mark on top of southwest abutment of pier of bridge over Little Hocking River has been destroyed. A new bench mark has been established in the northeast corner of the east pier of Baltimore & Ohio Southwestern Railroad water tank at Little Hocking River, the elevation of which is taken as 626.695 feet. The reliability of this elevation is not known.

Page 66, Madison; elevation of bench mark near south end of rock cut on curve should be 686.321 feet.

Page 66, Mabee; 4.5 miles west of, in center of foundation stone of Freedman Church; bronze tablet stamped "678 I." The elevation of this mark should be 679.856 feet.

Page 66, Harrison Township; copper bolt stamped "788 I" in sandstone ledge 8 feet east of center of road (in narrow ravine). The elevation of this mark should be 789.945 feet.

Page 68, Odell; 6 miles north of, aluminum tablet in south side of foundation of west end of spring house owned by Albert White. This bench mark is in the Cambridge quadrangle.

Page 83, Claylick; aluminum tablet in sandstone abutment of county bridge over canal. This tablet is reported to be stamped 799 instead of 790, as given in the bulletin.

Page 105, Africa; 0.25 mile west of, bronze tablet in top of south wing wa'' of iron bridge over Alum Creek. This mark has been destroyed.

Page 112, Grand Rapids; 2.8 miles north of, aluminum tablet in stone ' of schoolhouse at southwest corner of road crossing. Reported to have destroyed.

	Feet.
Mineral City, 3 miles northeast of, crossing of private road to house on west side of railroad, 50 feet west of public road, in top of stone of retaining wall on west side of track at crossing; chiseled square	968.89
Magnolia, 100 feet west of station, on north railroad right of way line, west of public road, 30 feet northwest of crossing, at foot of telegraph pole; iron post stamped "972"	971.796
Magnolia, in front of station; top of rail	973.6
Milepost 13; center of steel post (Pennsylvania R. R. bench mark)	1,000.0
Waynesburg, at north edge of town, opposite Pennsylvania R. R. station, in southwest corner of St. Paul's Reformed Church lawn, 3 feet from northwest corner of dwelling house and 3 feet from sidewalk; iron post stamped "993"	993.644
Waynesburg, street crossing at station; top of high rail	982.6
Waynesburg, center of town, in southwest corner of crossroads, on top of steel post; paint mark	1,002.50

Mineral City north along Baltimore & Ohio R. R. to point 3 miles south of Canton.

Mineral City, 150 feet northwest of Baltimore & Ohio R. R. station, at street crossing; top of rail	952.7
Sandyville, in front of station; top of rail	938.5
Sandyville, 160 feet north of station, 30 feet west of tracks, under northeast corner of water tank; iron post stamped "939"	939.037
East Sparta, 100 feet southwest of station, 40 feet south of lumber shed, north side of private road west to house, in fence corner; iron post stamped "959"	958.985
East Sparta, 2.3 miles north of, at northeast corner of road crossing, on east railroad right of way line, 30 feet north of public road, 30 feet east of railroad, 35 feet northwest of northwest corner of highway bridge over Nimischillen Creek; iron post stamped "965"	964.916
North Industry, 0.7 mile southeast of, 660 feet west of railroad crossing, northwest corner of bridge abutment of steel highway bridge over Nimischillen Creek; iron post stamped "981"	981.612
North Industry, in front of station; top of rail	1,000.1
North Industry, northeast corner of concrete platform around station, 200 feet south of road crossing, in top of curbing; chiseled square	1,000.91

CARROLLTON QUADRANGLE.

Waynesburg northeast along Pennsylvania R. R. to Bayard, thence east to point 2 miles east of East Rochester.

Waynesburg, 0.6 mile northeast of station, at road crossing in south abutment of east wing of steel highway bridge over Sandy Creek, in top stone; chiseled square	973.05
Malver, 0.3 mile west of Pennsylvania R. R. station, 150 feet north of road crossing, on west side of public road, at fence corner; iron post stamped "992"	992.474
Malvern, in front of Pennsylvania R. R. station; top of rail	998.4
Oneida, Pennsylvania R. R. and Wheeling & Lake Erie R. R. crossing; top of rail	1,013.7
Oneida, 75 feet northeast of Pennsylvania R. R. station, in west wing of south abutment of steel highway bridge over Sandy Creek; chiseled square	1,013.56

steel dies on the tablets or post caps, to the left of the word "Feet." The office adjustment of the notes and the reduction to mean sea level datum may so change some of the figures that the original markings are 1 or 2 feet in error. It is assumed that engineers and others who have occasion to use the bench-mark elevations will apply to the Director of the United States Geological Survey, at Washington, D. C., for the adjusted values, and will use the markings as identification numbers only.

Datum.—All United States Geological Survey elevations are referred to mean sea level, which is the level that the sea would assume if the influence of winds and tides were eliminated. This level is not the elevation determined from the mean of the highest and the lowest tides, nor is it the half sum of the mean of all the high tides and the mean of all the low tides, which is called the half-tide level. *Mean sea level is the average height of the water, all stages of the tide being considered.* It is determined from observations made by means of tidal gages placed at stations where local conditions, such as long, narrow bays, rivers, and like features, will not affect the height of the water. To obtain even approximately correct results these observations must extend over at least one lunar month, and if accuracy is desired they must extend over several years. At ocean stations the half-tide level and the mean sea level usually differ but little. It is assumed that there is no difference between the mean sea level as determined from observations in the Atlantic Ocean, the Gulf of Mexico, or the Pacific Ocean.

The connection with tidal stations for bench marks in certain areas that lie at some distance from the seacoast is still uncertain, and this fact is indicated by the addition of a letter or word to the right of the word "Datum" on tablets or posts. For such areas corrections for published results will be made from time to time as the precise-level lines of the United States Geological Survey or other Government organizations are extended.

Topographic maps.—Maps of the following quadrangles, wholly or partly in Ohio, have been published by the United States Geological Survey up to May 1, 1911. They may be obtained, except as noted, for 5 cents each or $3 a hundred on application to the Director of the Survey, at Washington, D. C.:

Akron.
Alliance.
Andover (Ohio-Pa.).
Antrim.
Arlington.
Ashland.
Ashtabula.
Athalia (Ohio-W. Va.).
Athens.
Belleville (W. Va.-Ohio).
Bellevue.
Berea.[1]
Bidwell.
Blanchester.
Bluffton.
Bowling Green.

[1] Cleveland and vicinity map includes parts of Cleveland, Euclid, and Berea shec

Bristolville.[1]
Brookville.
Cadiz.
Cameron (W. Va.-Ohio-Pa.).
Canton.
Chagrin Falls.
Chardon.
Chesterhill.[1]
Chillicothe.
Cincinnati (Ohio-Ky.) double sheet (10 cents.)[2]
Clarington (Ohio-W. Va.).
Cleveland.[3]
Cleveland and vicinity.[3]
Columbiana (Ohio-Pa.).
Columbus Grove.
Conesville.
Conneaut (Ohio.-Pa.).
Continental.
Dayton.[1]
Defiance.
Delaware.
Deshler.
Dublin.
East Cincinnati (Ohio-Ky.).[2]
East Columbus.
Elmore.
Euclid.[3]
Findlay.
Flushing.
Fostoria.
Frazeysburg.
Fremont.
Garrettsville.
Glenwood (W. Va.-Ohio).
Granville.
Greenville.
Guyandot (W. Va.-Ohio).[4]
Hamilton.
Huntington (W. Va.-Ohio-Ky.).[4]
Ironton (Ohio-Ky.).
Jefferson.[1]
Keno (Ohio-W. Va.).
Kenova (Ky.-W. Va.-Ohio).
Kent.
Kinsman (Ohio-Pa.).
Lancaster.
Lima.
Lisbon.
Logan.
London.
McClure.
McConnellsville.
Macksburg.
Marietta (Ohio-W. Va.).
Marion.
Mason.
Massillon.
Maumee Bay (Ohio-Mich.).
Medina.
Mentor.
Miamisburg.
Mount Sterling.
Napoleon.
Newark.
New Lexington.
New London.
New Martinsville (W. Va.-Ohio.)
New Matamoras (Ohio-W. Va.).
Oak Harbor.
Oberlin.
Ottawa.
Parkersburg (Ohio-W. Va.).
Perry.
Philo.
Point Pleasant (W. Va.-Ohio).
Pomeroy (Ohio-W. Va.).
Put-in-Bay.
Ravenna.
Ravenswood (W. Va.-Ohio).
St. Clairsville.
St. Henry.
St. Marys (W. Va.-Ohio).[1]
Salineville.
Sandusky.
Scio.
South Charleston.
Springfield.
Steubenville (Ohio-W. Va.-Pa.).
Sycamore.
Thornville.
Thurston.
Tiffin.
Toledo (Ohio-Mich.).
Upper Sandusky.
Vermilion.
Warren.
Waverly.

[1] Shows wooded areas.
[2] Cincinnati double sheet includes East Cincinnati and West Cincinnati sheets.
[3] Cleveland and vicinity map includes part of Cleveland, Euclid, and Berea sheets.
[4] Guyandot sheet shows part of Huntington quadrangle on larger scale.

Wellington.
Wellsville (Ohio-W. Va.-Pa.).
West Cincinnati (Ohio-Ky.).[1]
West Columbus.
Westerville.
West Manchester.
West Salem.
Wheeling (W. Va.-Ohio-Pa.).
Wilkesville.
Woodsfield.
Wooster.
Youngstown (Ohio-Pa.).
Zaleski.[2]
Zanesville.

PRIMARY LEVELING.

Brinkhaven, Canal Dover, Carrollton, Coshocton, Millersburg, Navarre, New Comerstown, Plimpton, Uhrichsville, and Wooster Quadrangles.

CARROLL, COLUMBIANA, COSHOCTON, HOLMES, KNOX, STARK, TUSCARAWAS, AND WAYNE COUNTIES.

The leveling was done in the Brinkhaven quadrangle in 1909 by S. R. Archer, and in 1910 by E. C. Bibbee; in the Canal Dover quadrangle in 1901 by J. B. Maguire and J. H. Wetzel, and in 1909 by S. R. Archer and C. B. Mincks; in the Carrollton quadrangle in 1900 by R. G. Defrees, and in 1909 by S. R. Archer and C. B. Mincks; in the Coshocton quadrangle in 1908 by C. H. Semper, and in 1909 by S. R. Archer; in the Millersburg quadrangle in 1909 by S. R. Archer, and in 1910 by E. C. Bibbee; in the Navarre quadrangle in 1910 by E. C. Bibbee; in the New Comerstown quadrangle in 1908 by C. H. Semper, in 1909 by S. R. Archer and C. B. Mincks, and in 1910 by E. C. Bibbee; in the Plimpton quadrangle in 1910 by E. C. Bibbee; in the Uhrichsville quadrangle in 1901 by J. H. Wetzel, in 1902 by B. J. Green, and in 1909 by C. B. Mincks; and in the Wooster quadrangle in 1910 by E. C. Bibbee.

BRINKHAVEN QUADRANGLE.

Point 2 miles southwest of Glenmont southwest and southeast along railroad to Warsaw.

	Feet.
Baddow Pass, 0.9 mile west of, on Cleveland, Akron & Columbus Ry., 400 feet west of T road west, at bridge 64 over wagon road, 20 feet north of road; iron post stamped "1050"	1,049.861
Brinkhaven, 1.8 miles east of, 35 feet west of railroad crossing, on north end of stone culvert under railroad; chiseled square	962.12
Brinkhaven, 25 feet north of main track, on northeast corner of station platform, Cleveland, Akron & Columbus Ry.; chiseled square	874.25
Brinkhaven, in northeast corner of schoolhouse yard; iron post stamped "896"	896.313
Brinkhaven, 1.2 miles south of, on south abutment, east side of overhead bridge 21; Pennsylvania R. R. bench mark	883.727
Brinkhaven, 2.4 miles south of, on Pennsylvania R. R., on concrete on south end, west side of abutment; chiseled square	867.71
Wintergreen (Cavallo Station), 25 feet west of post office, 75 feet east of railroad, in northwest corner of C. H. Summon's front yard; iron post stamped "878"	878.190
Wintergreen, 1.8 miles south of, on large, flat, sandstone rock on west side of railroad at private crossing; chiseled square	859.11

[1] Cincinnati double sheet includes East Cincinnati and West Cincinnati.
[2] Shows wooded areas.

	Feet.
Mineral City, 3 miles northeast of, crossing of private road to house on west side of railroad, 50 feet west of public road, in top of stone of retaining wall on west side of track at crossing; chiseled square	968.89
Magnolia, 100 feet west of station, on north railroad right of way line, west of public road, 30 feet northwest of crossing, at foot of telegraph pole; iron post stamped "972"	971.796
Magnolia, in front of station; top of rail	973.6
Milepost 13; center of steel post (Pennsylvania R. R. bench mark)	1,000.0
Waynesburg, at north edge of town, opposite Pennsylvania R. R. station, in southwest corner of St. Paul's Reformed Church lawn, 3 feet from northwest corner of dwelling house and 3 feet from sidewalk; iron post stamped "993"	993.644
Waynesburg, street crossing at station; top of high rail	982.6
Waynesburg, center of town, in southwest corner of crossroads, on top of steel post; paint mark	1,002.50

Mineral City north along Baltimore & Ohio R. R. to point 3 miles south of Canton.

Mineral City, 150 feet northwest of Baltimore & Ohio R. R. station, at street crossing; top of rail	952.7
Sandyville, in front of station; top of rail	938.5
Sandyville, 160 feet north of station, 30 feet west of tracks, under northeast corner of water tank; iron post stamped "939"	939.037
East Sparta, 100 feet southwest of station, 40 feet south of lumber shed, north side of private road west to house, in fence corner; iron post stamped "959"	958.985
East Sparta, 2.3 miles north of, at northeast corner of road crossing, on east railroad right of way line, 30 feet north of public road, 30 feet east of railroad, 35 feet northwest of northwest corner of highway bridge over Nimischillen Creek; iron post stamped "965"	964.916
North Industry, 0.7 mile southeast of, 600 feet west of railroad crossing, northwest corner of bridge abutment of steel highway bridge over Nimischillen Creek; iron post stamped "981"	981.612
North Industry, in front of station; top of rail	1,000.1
North Industry, northeast corner of concrete platform around station, 200 feet south of road crossing, in top of curbing; chiseled square	1,000.91

CARROLLTON QUADRANGLE.

Waynesburg northeast along Pennsylvania R. R. to Bayard, thence east to point 2 miles east of East Rochester.

Waynesburg, 0.6 mile northeast of station, at road crossing in south abutment of east wing of steel highway bridge over Sandy Creek, in top stone; chiseled square	973.05
Malver, 0.3 mile west of Pennsylvania R. R. station, 150 feet north of road crossing, on west side of public road, at fence corner; iron post stamped "992"	992.474
Malvern, in front of Pennsylvania R. R. station; top of rail	998.4
Oneida, Pennsylvania R. R. and Wheeling & Lake Erie R. R. crossing; top of rail	1,013.7
Oneida, 75 feet northeast of Pennsylvania R. R. station, in west wing of south abutment of steel highway bridge over Sandy Creek; chiseled square	1,013.56

	Feet.
Oneida, 0.6 mile northeast of railroad station, southeast corner of road crossing, 30 feet south of railroad; iron post stamped "1040"	1,040.050
Minerva, Pennsylvania R. R. and Lake Erie, Alliance & Wheeling R. R. crossing; top of rail	1,052.0
Minerva, 100 feet east of Pennsylvania R. R. station, east side of street, 40 feet north of railroad, foot of telephone anchor pole at street crossing; iron post stamped "1053"	1,052.708
Bayard, 0.4 mile southwest of, 50 feet north of center of road forks at schoolhouse, east end of stone culvert, in top; chiseled square	1,071.20
Bayard, 0.4 mile southwest, T at road south, southwest corner of road forks, inside fence corner; iron post stamped "1079"	1,079.455
Bayard, 1 mile southeast of, Pennsylvania R. R. crossing, in base of warning post at northeast corner of crossing; spike	1,094.04
East Rochester, in front of Pennsylvania R. R. station; top of rail	1,092.0
East Rochester, 1.7 miles east of station, at southwest corner of road crossing, west side of public road, 50 feet south of railroad, 20 feet south of Pennsylvânia R. R. right of way line, at fence line; iron post stamped "1095"	1,094.603

Sherodsville north and east along Wheeling & Lake Erie R. R. and highway to Carrollton triangulation station.

Atwood, 1.2 miles south of, 40 feet south and 10 feet east of road crossing, near telephone pole; iron post stamped "945"	945.231
Dellroy, 200 feet east of station, 15 feet north of railroad; iron post stamped "926"	925.781
Scott, 1.6 miles north of, 15 feet west of railroad, at railroad culvert 30-C; iron post stamped "953"	952.699
Scott, 1.8 miles north of, in culvert 30-B; aluminum tablet stamped "Prim. Trav. 1906, 955"	954.963
Deckman Duty brick plant, 0.8 mile north of, overhead railroad crossing, in stone abutment; cut mark, painted	1,052.06
Carrollton, courthouse, in front steps of south side, between pillars and walls of building; aluminum tablet	1,130.397
Carrollton, 2.6 miles east of, T road northeast of Washington Hall schoolhouse, on southeast abutment of iron bridge; chiseled square	1,064.82
Carrollton, 3.7 miles east of, on farm formerly owned by Mr. Campbell, now owned by George Ray, in marble slab at triangulation station; bronze tablet stamped "1377"	1,376.478

Oneida south along Wheeling & Lake Erie R. R. to Carrollton.

Oneida, 1.1 miles south of, 75 feet north of road crossing, top of east wing of south abutment of bridge 17-A; chiseled square	1,018.67
Oneida, 2.3 miles southeast of, northeast corner of road crossing, at fence corner; iron post stamped "1023"	1,023.672
Hibbetts, 2.2 miles southeast of, 40 feet northwest of the northwest corner of Stemples crossing, at fence corner of right of way line and north fence line of public road; iron post stamped "1051"	1,051.526
Carrollton, in front of Wheeling & Lake Erie R. R. station; top of rail	1,131.8
Carrollton, front entrance of courthouse, south side of steps, in top of stone base of marble columns, about 10 feet above pavement; aluminum tablet stamped "1130"	1,130.397

Minerva along highways southeast to Specht, thence southwest to Stemples Crossing on Wheeling & Lake Erie R. R.

	Feet.
Minerva, in front of Lake Erie, Alliance & Wheeling R. R. station; top of rail	1,046.0
Minerva, 4.3 miles southeast of, 30 feet east of track, at road crossing, north side of public highway; iron post stamped "1049"	1,049.413
Watheys, road crossing at, iron highway bridge, west side of railroad, in top of stone of south wing of east abutment; chiseled square	1,050.35
Watheys, 0.5 mile southeast of, 0.1 mile south of old Specht post office, at road crossing, north of railroad right of way line, west side of public highway, 40 feet north of track; iron post stamped "1049"	1,049.603
Specht, 2.2 miles southwest of, 0.25 mile west of Eckley, 3.2 miles east of Stemples crossing, northwest corner of crossroads, inside of fence line near maple tree 6 inches in diameter; iron post stamped "1199"	1,198.773
Stemples crossing, 2.3 miles east of, T road southeast, at point 6 feet above level of road, north of road at forks, in top of stone; chiseled square	1,144.69
Stemples crossing, 1.1 miles east of, in northwest corner of crossroads, in top of stone culvert; chiseled square	1,231.12
Hibbetts, 2.2 miles southwest of, 3.6 miles northwest of Carrollton, northwest corner of Stemples crossing, at fence corner on west railroad right of way line, 40 feet northwest of crossing; iron post stamped "1051"	1,051.526

Waynesburg southeast along highway to Dellroy.

Waynesburg, 2.1 miles southeast of, east of road, in top stone of culvert; chiseled square	1,160.83
Waynesburg, 2.5 miles southeast of, in southeast corner of crossroads, at fence corner; iron post stamped "1161"	1,161.333
Waynesburg, 3.5 miles southeast of, at five-points, in center of south crossroads, in top of stone; chiseled square	1,221.40
Waynesburg, 3.5 miles southeast by 1.2 miles south of, T road east, in top of stone at southeast corner; chiseled square	1,204.90
Waynesburg, 3.5 miles southeast of, T road west, near house east of road at forks in southwest corner of yard, inside fence corner; iron post stamped "1193"	1,193.790
Dellroy, 0.2 mile north of Wheeling & Lake Erie R. R. station, iron highway bridge, in top stone of approach to west wing of north abutment; chiseled square	926.02
Dellroy, 200 feet east of Wheeling & Lake Erie R. R. station, 15 feet north of tracks, inside fence corner at northeast corner of crossing; iron post stamped "926"	925.781

COSHOCTON QUADRANGLE.

Coshocton east to West Lafayette.

Coshocton, in front of station; top of rail	777.0
Coshocton, southeast corner of courthouse; aluminum tablet stamped "Prim.Trav.Sta.No. 57 777"	776.868

	Feet.
Coshocton, 3.2 miles east of, 900 feet west of milepost "P 119," in front face of concrete foundation of semaphore pole; aluminum tablet stamped "767"	767.632
Coshocton, 4 miles east of, crossing of Wheeling & Lake Erie R. R. and Pennsylvania R. R.; top of rail	769.5

Chili north along highway to Charm.

Chili, 0.1 mile north of, 150 feet south of crossroads, in top of east wing of north abutment of steel highway bridge over White Eyes Creek; chiseled square	813.64
Chili, 2.1 miles northwest of, 0.2 mile east and 0.3 mile south of section corner of secs. 14, 17, 13, and 18, Crawford Township, southwest corner at T road west; iron post stamped "857"	856.689
New Bedford, 0.3 mile southwest of, southwest corner at T road southwest, in top of stone; chiseled square	1,123.42
New Bedford, south part of town, at road forks, in west end of stone culvert, at top; chiseled square	1,136.16
New Bedford, general store 400 feet east of crossroads, north side of Main Street, in southeast corner of stone foundation; aluminum tablet stamped "1155"	1,154.958
New Bedford, 0.1 mile north of, in southwest corner at T road west, county line between Holmes and Coshocton Counties, in top of stone step; chiseled square	1,181.94
New Bedford, 2.8 miles north of, northwest corner at T road west; iron post stamped "1194"	1,193.742
Charm, 1.5 miles southwest of, four corners at, northeast corner of north road forks, in top of stone; chiseled square	1,208.63

Coshocton northwest along Pennsylvania R. R. to Warsaw.

Coshocton, in southeast corner of courthouse; aluminum tablet stamped "Prim.Trav.Sta.No. 57 777"	776.868
Roscoe, in center of crossroads, in top of foundation of well; chiseled square	774.24
Coshocton, 3.7 miles northwest of, 116 feet north of railroad, in east wing of north abutment of swing bridge at road crossing; aluminum tablet stamped "776"	776.400
Warsaw Junction, 2.4 miles east of, in top of south end of south wing of concrete dam in Walhonding River; aluminum tablet stamped "787"	786.869
Warsaw Junction, 1.4 miles east of, in top of west abutment, north wing, railroad bridge over highway; chiseled square	797.28

Warsaw north along Cleveland, Akron & Columbus Ry. to Killbuck.

Warsaw Junction, 3 miles northeast of, 60 feet west of railroad, at road crossing, in northeast corner of yard of W. H. Darling's residence, at foot of telephone pole; iron post stamped "794"	793.984
Warsaw Junction, 4 miles northeast of, in west wing of south abutment of railroad bridge over Killbuck River, in top stone; chiseled square	788.27
Metham, in front of station; top of rail	794.6
Metham, 0.1 mile north of station, northeast corner of road forks, 40 feet east of railroad, at railroad crossing; iron post stamped "793"	792.720

	Feet.
Metham, 1.7 miles north of, east wing of north abutment of railroad bridge 121 over Killbuck River; chiseled square	794.17
Blissfield, 175 feet west of station, south side of Main Street, 40 feet northeast of crossing, in northwest corner of yard; iron post stamped "Prim. Trav. Sta. No. 17 1907 796"	796.106
Blissfield, 1.1 miles northeast of, in north wing of west abutment of railroad bridge 120 over Killbuck River, in top stone; chiseled square	796.36
Helmick, in front of station; top of rail	797.0
Layland, 1.2 miles south of, south end of switch to sand mill, west right of way line, 50 feet west of track, 580 feet south of sand mill; iron post stamped "795"	794.622
Layland, in front of station; top of rail	798.9
Layland, 1.3 miles north of, in east wing of south abutment of railroad bridge 118 over Killbuck River; chiseled square	804.52
Layland, 2.1 miles north of, 0.8 mile south of Carpenter's switch, 0.8 mile north of railroad bridge over Killbuck River, east right of way line, 30 feet west of center of public road, 300 feet north of bend in public road to east; iron post stamped "804"	803.497

Grade south along highways to Coshocton.

Clark (Bloomfield), 0.8 mile north of post office, southwest corner at second-class road west; iron post stamped "941"	941.347
Clark, 0.3 mile north of, 200 feet south of T road east, in west wing of north abutment of small iron bridge; chiseled square	823.93
Clark, 2.5 miles south of, west side of Coshocton and Millersburg road, northeast corner of yard on property line, residence of D. C. Miley; iron post stamped "1127"	1,126.571
Clark, 4.5 miles southwest of, 1.3 miles northwest of Mound, T road southwest, 25 feet south of center of road forks, in top of west end of plank drain; copper nail	1,023.79
Mound, northeast corner of crossroads, 25 feet southwest of west end of steel bridge over Mill Creek; iron post stamped "817"	816.897
Mound, 2 miles south by 0.7 mile southeast of, southeast corner of road forks, 25 feet north of large maple tree, 60 feet northeast of small steel bridge over Little Mill Creek; iron post stamped "805"	805.366
Keene, 1.6 miles southeast of, north side of road forks at T road south, inside fence line, 50 feet north of center of road forks; iron post stamped "770"	769.687
Canal Lewisville, 2 miles north of, northeast corner at T road east, in top of stone; chiseled square	782.43
Canal Lewisville, 175 feet south of crossroads, in east wing of west abutment of steel highway bridge over canal; aluminum tablet stamped "774"	774.255
Coshocton, in northeast corner of courthouse; aluminum tablet stamped "Prim. Trav. Sta. No. 57 777"	776.868

MILLERSBURG QUADRANGLE.

Killbuck west along railroad 1.2 miles.

Killbuck, 1.2 miles west of, on coping stone of stone culvert under railroad at railroad crossing; chiseled square	807.12

Mount Hope southwest along road to Millersburg, thence east to Walnut Creek.

	Feet.
Mount Hope, 1.6 miles east of, on large rock on south side of road; chiseled square painted "1124.7"	1,124.63
Mount Hope, 15 feet southwest of southwest corner of Methodist Episcopal Church, 5 feet north of public road; iron post stamped "1285"	1,285.063
Benton, southwest corner of crossroads, 2 feet east of property line of E. R. Farver; iron post stamped "991"	990.910
Benton, 1.8 miles west of, southwest side of T road north, on stone ledge; chiseled square painted "1192.7"	1,192.52
Benton, 2.7 miles west of, south side of road at T road north; chiseled square painted "1103.6"	1,103.47
Benton, 2.8 miles west of, southwest side of T road west, in front of residence of W. H. Gindlesburger; iron post stamped "1128"	1,128.48
Millersburg, 1.5 miles east of, on west abutment, east side of bridge over Honey Run; chiseled square painted "879.204"	879.070
Millersburg, curb in front of courthouse; chiseled square	900.84
Millersburg, west side of courthouse, along wing wall of steps; iron post stamped "904," painted "904.3"	904.164
Millersburg, 1.1 miles east of, east end of small rock culvert under wagon road at T road east; chiseled square	976.640
Millersburg, 3.8 miles east of, southwest corner of crossroads at guidepost marked "Millersburg 4 miles, Berlin 3 miles, Benton 4 miles, Salbillo 2½ miles;" iron post stamped "1202"	1,202.102
Berlin, 1.6 miles west of, on top of large stone at T road south, opposite residence of Fred Mast; chiseled square painted "1062.8"	1,062.668
Berlin, in center of town, northwest corner of crossroads; iron post stamped "1292"	1,292.303
Walnut Creek, 2.5 miles west of, at southeast corner of T road south, in corner of field owned by E. M. Beachy; iron post stamped "1259"	1,258.716
Walnut Creek, 1.7 miles west of, on southwest corner of first step from bottom at schoolhouse at northeast corner of crossroads; chiseled square painted "1273.3"	1,273.134

Apple Creek southwest along railroad to point 1.1 miles south of Holmesville.

Apple Creek, 2.3 miles south of, southeast corner of crossroads, 100 feet east of railroad, at guidepost marked "Maysville 5 miles, Fredericksburg 2½ miles, Apple Creek 3½ miles;" iron post stamped "1034"	1,033.517
Fredericksburg, 1.1 miles north of, 100 feet north of railroad crossing, on south abutment, east side of bridge over Salt Creek, at milepost; chiseled square marked "H 50 C 94"	998.18
Fredericksburg, east side of schoolhouse yard, in front of church; iron post stamped "974"	973.874
Fredericksburg, 2.4 miles south of, 35 feet south of railroad at railroad crossing, on north end of bridge abutment on east side of Twin Bridge over Salt Creek; chiseled square	894.87
Holmesville, 500 feet north of station, 25 feet north of railroad, near right of way at railroad crossing; iron post stamped "871"	870.409

Millersburg northwest along railroad to Shreve.

	Feet.
Millersburg, 2.7 miles north of, 690 feet east of Cleveland, Akron & Columbus Ry. at T road east, west of public road, in corner of field opposite Alvin Slavock's residence; iron post stamped "832"	831.688
Holmesville, in front of station; top of rail	833.6
Hard, 100 feet west of station, south side of public road; iron post stamped "837"	837.298
Hard, in front of station; top of rail	836.5
Kauke, 10 feet northwest of station, 10 feet south of road, on right of way at railroad crossing; iron post stamped "862"	861.808
Shreve, 2.6 miles east of, north side of bridge 124, on east abutment; chiseled square marked "G. B."	837.86
Shreve, 2.3 miles east of, on west abutment, north side of bridge 125; chiseled square painted "839.0"	838.98

Millersburg south along railroad 3 miles.

Millersburg, 2.6 miles south of, on west and north side of bridge approach at railroad crossing; chiseled square painted "813"	812.89
Millersburg, 3.1 miles south of, 3 miles east of Killbuck, at Hardy's switch, 280 feet east of fork of road, southeast corner of road; iron post stamped "811"	810.594

Killbuck north along railroad to Shreve.

Killbuck, 1.4 miles northwest of, at crossroads, on north end of stone culvert; chiseled square painted "844.1"	844.12

Charm northeast along highways to point 3.1 miles southwest of Walnut Creek.

Charm, center of town, opposite post office, at southwest corner of yard on east side of road at T road east, 130 feet northwest of road forks; iron post stamped "1047"	1,046.628
Walnut Creek, 3.1 miles southwest of, 550 feet east of Shelter schoolhouse; iron post stamped "Prim.Trav.Sta.No.40, 1040"	1,040.015
Walnut Creek, 3.1 miles southwest of, about 600 feet east of Shelter schoolhouse, on south abutment, west side of bridge at T road north; chiseled square painted "1028.3"	1,028.24

Killbuck east along highway to Charm.

Killbuck, 450 feet west of station, steel bridge on main line Cleveland, Akron & Columbus Ry. over Killbuck River, in north wing of east abutment; aluminum tablet stamped "Prim.Trav.Sta.No.16, 1907, 807"	807.29
Killbuck, in front of Cleveland, Akron & Columbus Ry. station; top of rail	810.6
Killbuck, 3 miles east of, 280 feet south of Hardy's switch, southeast corner of forks of road; iron post stamped "811"	810.594
Grade, 0.25 mile west of, road forks at old post office, west side of road; iron post stamped "1162"	1,162.146
Saltillo, northeast corner of crossroads, inside fence line; iron post stamped "Prim. Trav. Sta. No. 24, 1907, 1217"	1,216.898
Charm, 1.25 miles northwest by 1.25 miles west of, four corners, southwest corner of north road forks, in top of stone; chiseled square	1,214.22

	Feet.
Charm, east part of town, T road southwest at schoolhouse, 90 feet northwest of road forks, in top of west wing of south abutment of small iron bridge; chiseled square	1,030.51

NAVARRE QUADRANGLE.

Wilmot northwest along highway to Kidron.

Wilmot, south side of Maple Street at T road west to Winesburg, 75 feet east of Methodist Episcopal Church; iron post stamped "1024"	1,023.496
Wilmot, 1.1 miles northwest of, on east abutment, south side of bridge over Little Sugar Creek at Y road; chiseled square	1,000.46
Wilmot, 2.4 miles northwest of, south of Mount Eaton Road at T road north; iron post stamped "1184"	1,184.168
Wilmot, 3.1 miles northwest of, on south abutment west side of bridge over creek; chiseled square	1,026.33
West Lebanon (Pem Station), 0.7 mile east of, on north abutment, east side of bridge 300 feet south of railroad; chiseled square	986.30
West Lebanon (Pem Station), north side of railroad, on right of way, 25 feet east of wagon road; iron post stamped "988"	988.126
West Lebanon, 1.1 miles west of, 50 feet north of railroad at railroad crossing; on south abutment, east side of bridge over Little Sugar Creek; chiseled square	1,001.64
West Lebanon, 1.7 miles west of, on south abutment, west side of bridge over Little Sugar Creek, at railroad crossing; chiseled square	1,013.08
West Lebanon, 3.4 miles west of, 60 feet north of railroad at railroad crossing, on north abutment, east side of bridge over Little Sugar Creek, chiseled square	1,077.004
Kidron, center of town, southwest corner of crossroads; iron post stamped "Prim. Trav. Sta. No. 38, 1104"	1,103.849

Canal Dover west along highway to Sugar Creek, thence north along railroad to Beach City.

Canal Dover, 3.5 miles west of, north of road at T road south; iron post stamped "932"	932.005
Canal Dover, 6.4 miles west of, northwest corner of T road north; iron post stamped "1038"	1,037.508
Canal Dover, 7.2 miles west of, southwest corner of crossrods; iron post stamped "Prim. Trav. Sta. No. 41, 1003"	1,002.574
Sugar Creek, 175 feet north of station, 15 feet east of public road; iron post stamped "992"	992.000
Sugar Creek, south end of station platform; top of east rail	990.7
Sugar Creek, 2.1 miles north of, west side of public road, 15 feet east of railroad crossing, on stone; chiseled mark painted "980.2"	980.03
Barrs Mills, 150 feet south of railroad crossing, on north abutment west side of railroad bridge; chiseled square	975.41
Barrs Mills, 490 feet north of railroad station at railroad crossing, 25 feet west of Wheeling & Lake Erie R. R. on railroad right of way; iron post stamped "969"	968.407
Barrs Mills, 1 mile north of, 9 feet east of railroad at whistle post; chiseled square on large rock, marked "Barrs Mills 1 mile" on whistle post	972.42

	Feet.
Dundee, in front of station, on Wheeling & Lake Erie R. R. right of way; iron post stamped "972"	971.702
Dundee, 1.2 miles north of, on north abutment, west side of railroad bridge; chiseled square painted "959.9"	959.76
Dundee, 2.5 miles north of, 60 feet north of telephone pole 1810, on right of way of Wheeling & Lake Erie R. R., 60 feet west of railroad; iron post stamped "960"	959.836
Beach City, at northwest corner of schoolhouse; iron post stamped "1009"	1,008.838
Beach City, Baltimore & Ohio R. R. crossing, 75 feet north of station	968.6

Beach City southwest along highway to Winesburg.

Wilmot, 0.5 mile southwest of, on north side of, under wagon road, stone-arch culvert 300 feet west of T road south; chiseled square	1,018.87
Wilmot, 0.9 mile southwest of, south end of stone culvert under wagon road, on line between Stark and Holmes Counties; chiseled square painted "1019.3"	1,019.11
Wilmot, 2.8 miles southwest of, in northwest corner of lot owned by Christian Weiss, 25 feet northeast of house; iron post stamped "1039"	1,038.837
Winesburg, 1.4 miles east of, on north side of stone-arch culvert; chiseled square painted "1079.3"	1,079.16
Winesburg, in southwest corner of schoolhouse yard, 325 feet west of crossroads; iron post stamped "1311"	1,311.316
Winesburg, 2.5 miles southwest of, at southeast corner of crossroads, about 500 feet west of schoolhouse; iron post stamped "Prim. Trav. Sta. No. 39, 1186"	1,185.423

Winesburg southwest along highway to Charm.

Winesburg, 1.3 miles south of, east end of stone culvert; chiseled square painted "1026.3"	1,026.14
Walnut Creek, 2.8 miles north of, northwest corner of crossroads, at guidepost marked "Dundee 4½ miles, Berlin 4 miles, Trail 1 mile, Walnut Creek 3 miles;" iron post stamped "1156"	1,155.825
Walnut Creek, 1.6 miles north of, on north end of concrete culvert at T road east; chiseled square painted "1054.8"	1,054.68
Walnut Creek, southeast corner of crossroads, on curb opposite post office; chiseled square	1,190.375
Walnut Creek, in front of schoolhouse, west side of yard; iron post stamped "1198"	1,197.458
Walnut Creek, 0.6 mile south of, southwest corner of crossroads, on stone; chiseled square painted "996.5"	996.403

NEW COMERSTOWN QUADRANGLE.

West Lafayette east via New Comerstown to Bernice.

West Lafayette, in front of station; top of rail	802.0
West Lafayette, northwest corner of public school grounds, 120 feet south of Pennsylvania R. R.; iron post stamped "Prim. Trav. Sta. No. 58 809"	809.351
Isleta, in front of station; top of rail	792.1
Isleta, 265 feet east of station, 25 feet north of track, in railroad culvert; aluminum tablet stamped "791"	790.637

	Feet.
New Comerstown, in front of station; top of rail	802.9
New Comerstown, in front step of Fountain Hotel, northwest corner, 1 foot from sidewalk; aluminum tablet stamped "805"	805.191
New Comerstown, in foundation of high school building, 6 feet south of entrance from College Street; aluminum tablet stamped "809"	808.623
Bernice, 2 miles west of, in north abutment, east side of iron bridge over Dunlap Creek; aluminum table stamped "802"	803.178
Bernice, 0.6 mile west of, on west abutment, north side of iron bridge; chiseled square, painted "811.9"	812.88

New Comerstown north along Pennsylvania R. R. to Joyce (the error distributed in this line is excessive).

New Comerstown, 2.4 miles northeast of, about 0.1 mile east of road forks at road crossing, in top of south wing of east abutment of steel bridge; chiseled square	815.50
New Comerstown, 3 miles northeast of, 550 feet east of Pennsylvania R. R., west side of road, at T road east; iron post stamped "827"	826.953
Wolf, 2.6 miles north of, 30 feet east by 10 feet south of overhead railroad crossing; iron post stamped "890"	889.652
Stone Creek, 1.9 miles north of, at road crossing, in north abutment of bridge over stream; chiseled square	905.82
Stone Creek, 3.1 miles north of, 20 feet east of railroad, at private road crossing; iron post stamped "901"	900.880

West Lafayette north along Wheeling & Lake Erie R. R. to Chili.

West Lafayette, east of Pennsylvania R. R. station, at center of road crossing; top of north rail of north track	802.4
West Lafayette, 1.4 miles north of, in top of west wing of north abutment of steel highway bridge over Tuscarawas River; chiseled square	778.73
West Lafayette, in front of Wheeling & Lake Erie R. R. station, at road crossing; top of rail	777
West Lafayette, 2.3 miles north of, on Wheeling & Lake Erie R. R. east right of way line, north side of road at road crossing, inside fence corner; iron post stamped "779"	779.269
Fresno, in front of station; top of rail	788.4
Fresno, 110 feet west of Wheeling & Lake Erie R. R., in southeast corner of schoolhouse grounds; iron post stamped "Prim.Trav. Sta.No. 27 1907 785"	784.999
Chili, south end of station platform, 35 feet east of track, 50 feet west of crossroads; iron post stamped "PrimTrav.Sta.No. 26 1907 823"	822.757
Chili, 0.9 mile west of, southwest corner of crossroads, at foot of mail-box post, 15 feet west of fence corner; iron post stamped "993"	993.143

Sugar Creek southwest along railroad to New Bedford.

Sugar Creek, 3.4 miles south of, 25 feet west of railroad, 10 feet south of wagon road; iron post stamped "998," painted "998.4"	998.226
Baltic, in yard at Bixler Hotel; iron post stamped "1041"	1,041.305
Baltic, 2.6 miles west of, at Y road; iron post stamped "1151"	1,150.916

Baltic southeast along highway to Stone Creek.

	Feet.
Flat schoolhouse, in northwest corner of foundation; aluminum tablet stamped "1089"	1,088.983
Baltic, 4 miles west of, on east side of small rock culvert; chiseled square painted "1048.8"	1,048.57
Baltic, 5.4 miles east of, on east end of stone arch culvert at T road; chiseled square painted "1068.2"	1,067.94
Baltic, 6 miles east of, about 500 feet east of William Thomas's residence; iron post stamped "1126"	1,126.132
Stone Creek, 3.5 miles west of, in northwest corner of Angel schoolhouse yard; iron post stamped "970"	970.398
Stone Creek, in foundation at northwest corner of P. E. Buehler's store; aluminum tablet stamped "932"	931.648

PLIMPTON QUADRANGLE.

Killbuck north along railroad to Shreve.

Killbuck, 2.5 miles northwest of, 7 feet east of center of road, in center on large sandstone rock; chiseled square with cross painted "882.4"	882.43
Killbuck, 2.9 miles northwest of, 1.1 miles south of Welcome, on Killbuck-Shreve Road, at southwest corner of crossroads; iron post stamped "920"	920.071
Welcome, center of town, 15 feet east of crossroads, on northwest corner of bridge abutment; chiseled square painted "930.5"	930.45
Welcome, 0.9 mile north of, at guidepost marked "Paint Valley 2½ miles, Shreve 9 miles, Welcome 1 mile," at northwest corner of T road; iron post stamped "1001"	1,000.833
Welcome, 2.1 miles north of, in center of T road, on cornerstone rock; chiseled square painted "1102"	1,101.98
Shreve, 6.5 miles south of, at northwest corner of T road north; iron post stamped "1029"	1,028.521
Shreve, 6.4 miles south of, at northwest corner of T road at guidepost, marked "Shreve 4 miles, Paint Valley 3 miles, Nashville 5 miles, Holmesville 6 miles;" iron post stamped "Prim.Trav.Sta. No. 23, 1187"	1,187.003
Shreve, 3.4 miles south of, northwest corner of crossroads at guidepost marked "Holmesville 6, Welcome 8, Shreve 3½;" iron post stamped "1139"	1,138.697
Shreve, 1 mile south of, northwest corner of T road north, on rock; chiseled square	918.4
Shreve, under ticket-office window; southeast corner of water table	917.06

Point 1.2 miles west of Killbuck west along railroad to point 2 miles southwest of Glenmont.

Killbuck, 3.1 miles east of, on Cleveland, Akron & Columbus Ry., 60 feet south of milepost marked "C 74 H 70," on northeast corner of stone culvert under railroad; chiseled square	825.49
Glenmont, 2 miles east of, 30 feet south of railroad, 25 feet west of wagon road, 1,000 feet east of milepost marked "C 73 H 71;" iron post stamped "836"	835.748

	Feet.
Glenmont, 40 feet north of center of main track, in northeast corner of grass plot; iron post stamped "Prim.Trav.Sta.No.17 868"	868. 268
Glenmont, 2 miles west of, 25 feet north of railroad, at private crossing 200 feet south of T road north, on sandstone rock; chiseled square	988. 09

Glenmont south along highway toward Warsaw.

Glenmont, 0.6 mile south of, west of road on top of hill, on large stone at gatepost; chiseled square	1, 192. 47

UHRICHSVILLE QUADRANGLE.

At Station 15 post office.

Station 15 post office, Pittsburg, Cincinnati, Chicago & St. Louis Ry. stone bridge 86, on northeast coping of northeast wing wall; aluminum tablet stamped "868 STEUBENVILLE"	868. 622

Tennett's tunnel north to Tippecanoe and east.

Tippecanoe, southwest corner of Daviess and Spencer Streets, north foundation wall of dwelling; bronze tablet stamped "882 STEUBENVILLE"	881. 736
Tippecanoe, 0.8 mile east of, covered bridge over Brushy Fork, on south-wing wall of east abutment; chiseled square	869. 62

Joyce north along Pennsylvania R. R. to near Canal Dover (part of adjusted line New Comerstown to Canal Dover, the closure error of which was excessive).

Joyce, 1.1 miles north of, 25 feet west and 10 feet south of road crossing; iron post stamped "873"	872. 644

WOOSTER QUADRANGLE.

Kidron northwest along highway to point 1.9 miles north of Apple Creek.

Kidron, 2.2 miles west of, 25 feet south of railroad on west side of public road at crossing, on right of way; iron post stamped "1128"	1, 127. 471
Apple Creek, 1.9 miles north of, on Cleveland, Akron & Columbus Ry., 350 feet north of switch leading to Kidron, on southeast corner, east end of small concrete culvert under railroad at railroad crossing; chiseled cross	1, 089. 80

Apple Creek north along Cleveland, Akron & Columbus Ry. to Orrville.

Apple Creek, 300 feet south of station, at railroad crossing, in southeast corner of park; iron post stamped "1029"	1, 028. 294
Apple Creek, 1.9 miles north of, southeast corner, east end of small concrete culvert under railroad at railroad crossing, 350 feet north of switch to Kidron; chiseled cross	1, 089. 80
East Union, 1.2 miles south of, 895 feet south of milepost marked "C 102 H 92;" chiseled square on southeast corner east side of small stone culvert under railroad	1, 116. 032

	Feet.
East Union, 700 feet east of crossing of State Road, on southwest corner east abutment of highway bridge over creek; bronze tablet stamped "1074 CANTON"	1,075.12
Orrville, in front entrance of town hall, in water table; aluminum tablet stamped "1066"	1,064.96

Jackson, Laurelville, and Oakhill Quadrangles.

HOCKING, JACKSON, AND VINTON COUNTIES.

The elevations in the following list were determined in 1910. Th work in the Jackson quadrangle was done by C. E. Mills and C. E Shaw and that in the Laurelville quadrangle by C. E. Mills, C. E Shaw, and S. R. Archer. Previous work along the west border o the Laurelville quadrangle was done by H. W. Peabody in 1906 an along the east border of the Jackson quadrangle by E. L. McNair i 1897. The work in the Oakhill quadrangle was done by C. E. Mill in 1910.

LAURELVILLE QUADRANGLE.

Adelphia east via South Perry to Gibsonville, thence south to Mosley Chapel.

	Feet.
Adelphia, northeast corner of post-office building in water table; aluminum tablet stamped "838"	837.78
Laurelville, 2 miles northeast of, southeast corner of T road east; iron post stamped "772 OHIO"	772.07
Laurelville, 2 miles northeast by 0.6 mile east of, 60 feet west of road forks, at T road northwest, in top of east abutment, south-wing wall, of small iron bridge; chiseled square	772.70
South Perry, 0.8 mile west of, south side of road at T road north, in base of small maple tree; spike	784.40
South Perry, 0.5 mile west of, south side of road, on east end of lower step of Baptist Church; painted square	794.11
South Perry, west edge of town, top of east abutment, south wing, of iron bridge over Toad Run, west side of crossroads; painted square	794.46
South Perry, southeast corner of Jesse Cave's residence; iron post stamped "804 OHIO"	804.06
South Perry, 0.4 mile east of, north side of T road south, on top of stone; square	802.2
South Perry, 1.4 miles east of, 60 feet west of T road west, on top of west-wing wall of east abutment to steel bridge; painted square	822.3
South Perry, 2.8 miles northeast of, in front of Mound Crossing schoolhouse, 40 feet north of center of crossroads; iron post stamped "Prim. Trav. Sta. No. 8 848," 1906"	848.1
Rock House, 0.4 mile south and east of, about 250 feet west of bend in road to northeast, in top of stone under fence on north side of road; chiseled square	1,114.20
Gibsonville, 1.3 miles west of, south side of road at T road north; spike in base of tree	1,031.2
Gibsonville, 1 mile west of, north side of road at T road south; spike in root of small elm tree	1,133.3
Gibsonville, northeast corner of Methodist Church; iron post stamped "1114 OHIO"	1,113.6

Feet.

Gibsonville, 1.5 miles south of, in center of road forks a T road southeast, in top of stone; chiseled square 1,075.52

Gibsonville, 1.5 miles south by 0.8 mile southeast of, in front of Scheik's residence, in center of road, in top of stone; chiseled square 1,071.38

Gibsonville, 1.5 miles south by 1.6 miles southeast of, west of road south, 100 feet south of road forks and 30 feet south of southwest corner of steel highway bridge over Pine Creek; iron post stamped "762" 761.419

Gibsonville, 1.5 miles south by 2.3 miles southeast of, spike in base of tree on east side of road at top of hill 1,060.14

Cedar Grove Church, 350 feet southwest of, southwest corner of T road south; iron post stamped "897" 897.084

Wesley Chapel, about 1 mile east of, on south side of east abutment of small iron bridge; chiseled square 829.78

South Bloomingville, 3.8 miles east of, 0.2 mile north of Wesley Chapel, west of road at forks; iron post stamped "1066" 1,066.013

Laurelville along Columbus & Southern Ry. to South Bloomingville, thence by public road to Wesley Chapel.

Laurelville, northwest corner of public square, on top of concrete curbing at corner; painted square 739.58

Laurelville, 2.3 miles southeast of, 400 feet southeast of Karshner schoolhouse, 500 feet east of railroad, northwest corner of private road west; iron post stamped "733" 733.272

Haynes, southeast corner of T road northeast, 60 feet east of road forks; iron post stamped "694" 694.020

Reeds, northwest corner of road crossing, 75 feet north of railroad, in southwest corner of yard; iron post stamped "682" 682.076

South Bloomingville, road crossing at station; top of rail 690.7

South Bloomingville, 1.6 miles northeast of, south side of road at T road north, painted square on root of stump of tree 1,020.51

South Bloomingville, 3.1 miles east of, in southeast corner of T road south; chisel mark on stone 1,050.23

Cox via Eagle Mills, Walnut Grove Church, Royal, Stella, and Hue to Wesley Chapel.

Cox, 1 mile east of, south side of road at T road north, on stone; chiseled square 630.71

Cox, 1.25 miles east by northeast, west end of culvert at northwest corner of road forks; chiseled square painted "636.17" 636.11

Eagle Mills, 0.1 mile north of post office, southeast corner of road forks, inside of fence, south side of wooden bridge and about 10 feet from road; iron post stamped "648 OHIO" 647.945

Eagle Mills, 2.9 miles east by 1 mile west of, 3 feet north of telephone pole, about 50 feet south of creek, west of Vander school; iron post stamped "678 OHIO" 677.804

Vander school, 0.5 mile southeast of, Ural post office, at southwest corner of road forks, about 75 feet from intersection; spike in root of oak tree painted "740.585" 740.47

Royal, 60 feet east of covered bridge, at road forks; iron post stamped "726" .... 72[illegible]

Royal, 3.4 miles northeast of, Low Gap, northwest corner of crossroads; spike in root of oak tree painted "994.052" .... 9[illegible]

	Feet.
Stella, outside southeast corner of cemetery fence, about 10 feet north of telephone pole and 100 feet south of church at northwest corner of crossroads; iron post stamped "1056 OHIO"	1,055.412
Milhon school, 0.8 mile northeast of Stella, at road forks, spike in root of large oak tree; painted "1071.883"	1,071.73
Stella, 2.6 miles northeast of, at northeast corner of road forks, spike in root of hickory tree; painted "1045.109"	1,045.00
Stella, 3.4 miles northeast of, about 0.8 mile southwest of Hue, at southwest corner of road forks, spike in root of tree; painted "1036.381"	1,036.29
Hue, about 0.8 mile west of, in northwest corner of H. S. Honnold's yard, outside fence at road forks; iron post stamped "Prim. Trav. Sta. 1906, 865 OHIO"	865.354

Stella to Creola.

Creola, Kirkendall's store and post office, 7 feet from east wall (front) of store in top stone of south foundation wall; bronze tablet stamped "760 OHIO"	760.159

Allensville to Royal.

Allensville, 75 feet west of Darby's store, south of road, inside hitch rack; iron post stamped "682 OHIO"	681.426

JACKSON QUADRANGLE.

Beecher along Baltimore & Ohio Southwestern R. R. to Hamden.

Beecher, 2.7 miles east of, north of Baltimore & Ohio Southwestern R. R. track, 20 feet north of and 75 feet west of bridge abutment, 50 feet east of road crossing, bridge 115–25; iron post stamped "611 OHIO"	610.596
Ray, 0.4 mile east of, about 20 feet north of railroad track, east side of road at forks; iron post stamped "622 OHIO"	621.503
Byer, in front of station; top of rail	615
Byer, 75 feet east of Cincinnati, Hamilton & Dayton Ry. station, 50 feet north of track, on east side of road at road crossing; iron post stamped "640 OHIO"	639.686
Byer, junction of Baltimore & Ohio Southwestern R. R. and Cincinnati, Hamilton & Dayton Ry.; top of north rail	644
Richland, 75 feet southwest of station, south side of track and 25 feet east of road; iron post stamped "701 OHIO"	701.011
Summit, 75 feet south of track, 20 feet west of road near fence corner at road crossing; iron post stamped "786 OHIO"	785.496
Hamden, in front of Baltimore & Ohio Southwestern R. R. station; top of rail	713
Hamden, 0.5 mile east of, on coping of Baltimore & Ohio Southwestern R. R. culvert; cut (Coast and Geodetic Survey bench mark III)	705.481

Byer north via Ox to Allensville.

Byer, 0.3 mile north of, top of stone at road intersection; paint mark "644.596"	644.47

Byer, 3.8 miles north of, 5 feet northwest of mail-box post, near walnut tree to southwest at northwest corner of road forks; iron post stamped "826 OHIO" ---- Feet. 825.925

Ox, 0.3 mile north of, southwest corner of road forks, on top of stone; paint mark "748.855" ---- 748.72

Glade along Detroit, Toledo & Ironton Ry. to Jackson.

Glade, 435 feet south of station, east of road in wood lot; iron post stamped "Prim. Trav. Sta. No. 20, 687" ---- 686.862

Glade, road crossing at station; top of rail ---- 689.6

Cove, rear of post office, 25 feet west of railroad; iron post stamped "691" ---- 690.581

Cove, 2.6 miles northeast of, Cochran switch, southeast side of track, 1 foot from right-of-way fence; iron post stamped "674" ---- 674.269

Cove, 5.1 miles northeast of, northwest corner of Sunshine mine switch, 30 feet north of north main line of Detroit, Toledo & Ironton Ry., and 500 feet west of switch stand; iron post stamped "650" ---- 650.284

Jackson, Detroit, Toledo & Ironton Ry. station, northeast corner of platform, on stone curbing; chiseled mark painted "649.63" ---- 649.668

Jackson, northeast corner of crossing of Main and Portsmouth Streets, southwest corner of public square, southeast corner of county surveyor's office building; iron post stamped "700" ---- 699.822

Jackson along Cincinnati, Hamilton & Dayton Ry. to Byer.

Jackson, crossing of Detroit, Toledo & Ironton Ry. and Hocking Valley Ry ---- 648.60

Chapman, road crossing at station, north side of road, west side of railroad, in southeast corner of yard; iron post stamped "678" ---- 677.717

Coalton, 500 feet east of Cincinnati, Hamilton & Dayton Ry. station, northeast corner of crossroads, at road crossing, near warning post; iron post stamped "702" ---- 702.379

Coalton, in front of Cincinnati, Hamilton & Dayton Ry. station; top of rail ---- 698.13

Coalton, 2.5 miles northwest of, road crossing at Glenn Hall, 15 feet north of road and 20 feet west of railroad, 3 feet from warning post; iron post stamped "667" ---- 666.555

Coalton, 3.9 miles northwest of, 30 feet south of road crossing, west side of track; bolt head in north end of bridge No. 152; painted "653.4" ---- 653.41

Sunshine mine switch north via Oakland Church and Leach to Ray.

Jackson, 2.9 miles west by 2.4 miles northwest of, road forks at Oakland Church and schoolhouse, northeast corner of forks, 5 feet from row of mail boxes; iron post stamped "835" ---- 835.220

Leach, 1.3 miles southeast of, southeast corner of T road, south, 15 feet south of Chillicothe-Jackson pike, on stone; chisel mark ---- 709.48

Leach, 0.8 mile southeast of, top, north end of west abutment of iron bridge over Salt Creek at T road northeast; chiseled cross painted "622.24" ---- 622.36

	Feet.
Leach, 0.3 mile southeast of, 300 feet west of iron bridge over Salt Creek, in center of road forks, on stone; chisel mark painted "627.55"	627.67
Leach, in front of George H. Greene's house, opposite store, 150 feet northwest of T road, east; iron post stamped "621"	620.898
Ivy, 2.5 miles south of Ray, 200 feet west of store at southeast corner of T road, north; iron post stamped "958 OHIO"	957.636

OAKHILL QUADRANGLE.

Edmunds switch along Baltimore & Ohio Southwestern R. R. to Keystone.

South Webster, in concrete curbing, east end of station platform, 10 feet west of road crossing; chiseled square	702.47
Bloom, 0.2 mile south of, 20 feet north of road and 15 feet east of railroad at road crossing; iron post stamped "633"	633.170
Elfort, on north end of concrete curbing of station platform; chiseled square painted "665.5"	665.50
Elfort, 1.1 miles northeast of, 60 feet north of milepost "H 31–P 25," 10 feet south of road, 10 feet west of railroad, at road crossing; iron post stamped "676"	675.857
Black Fork, center of concrete curbing of station platform; chiseled square	687.06
Black Fork, 10 feet north of northeast corner of station, 20 feet west of railroad; iron post stamped "687"	686.884
Oakhill, 35 feet west of railroad, 15 feet south of center of road. road crossing at Baltimore & Ohio Southwestern R. R. station; iron post stamped "707"	707.417
Clay, 40 feet south of railroad and 20 feet east of road at road crossing near station; iron post stamped "695"	694.964
Camba, 25 feet south of station, 20 feet east of track, under overhead highway bridge; iron post stamped "728"	728.538

Bainbridge, Georgetown, Greenup, Hillsboro, Manchester, Maysville, Otway, Peebles, Portsmouth, Scioto, Vanceburg, and West Union Quadrangles.

ADAMS, BROWN, PIKE, AND SCIOTO COUNTIES.

The elevations in the following list were determined in 1910, the field work being done by C. B. Shaw, J. W. Janssen, Howard Clark, and C. E. Mills. Results of additional work done in the Scioto quadrangle by E. L. McNair in 1897 and in the Scioto and Otway quadrangles by W. H. Monahan in 1906 have been published in Bulletin 411.

SCIOTO QUADRANGLE.

New Boston along Baltimore & Ohio Southwestern R. R. to Edmunds switch.

	Feet.
New Boston, 1 foot east of station sign post; iron post stamped "534"	533.728
Sciotoville, about 360 feet north of Baltimore & Ohio Southwestern station, 30 feet west of track; iron post stamped "Prim. Trav. Sta. No. 26, 548"	547.899
Sciotoville, 30 feet east of southeast corner of station platform, 15 feet north of railroad; iron post stamped "545"	545.394

	Feet.
Sciotoville, 1 mile northeast of, in base of switch stand on east side of track at south end of switch; spike head	550.04
Slocums, 0.8 mile northeast of, southwest corner of road crossing, near telegraph pole; iron post stamped "554"	554.291
Gepharts, 400 feet southwest of station, 50 feet south of road crossing, 60 feet east of trestle; iron post stamped "671"	670.806
Scioto Furnace, 10 feet from north end of concrete curbing of station platform; chiseled square	602.98
Scioto Furnace, 0.7 mile northeast of, at Edmunds switch, trestle 374 over creek and road, in north end of east guard rail; bolthead	605.51
Edmunds switch, at sign post between switch and main line of Baltimore & Ohio Southwestern R. R.; iron post stamped "608"	607.562

Portsmouth north along Norfolk & Western Ry. (Cincinnati division).

Portsmouth, 3.5 miles northwest of, north end of switch at Wharton Station, 50 feet west of railroad, 25 feet southwest of southwest corner of canal bridge, 15 feet south of private road east and 20 feet east of Portsmouth and Galena Pike; iron post stamped "529"	528.775

Davis, northeast along public roads via Scioto (Harrisonville) to Massie.

Davis, 1.1 miles north of, about 5 miles north of Portsmouth, west side of track in south abutment of iron bridge over Portsmouth and Chillicothe Pike; aluminum tablet stamped "559"	557.869
Portsmouth, about 5 miles north by 0.6 mile east of, west side of Fort Hill, on stone, north side of road; chisel mark painted "798.1"	797.94
Crone, 1.2 miles southwest of post office, on Portsmouth-Harrisonville Pike, at T road northwest, 0.25 mile east of Long Run Methodist Episcopal Church and 850 feet south of Long Run United Brethren Church, northwest corner of road forks; iron post stamped "747"	747.108
Crone, 0.6 mile northeast of, T road northwest, 50 feet north of road forks, north abutment, west side of small wooden bridge over creek; chiseled square painted "684.4"	684.31
Scioto (Harrisonville), 3.1 miles southwest of, on Portsmouth-Harrisonville Pike, northeast corner of road forks, at A. Oertal's farm; iron post stamped "685"	685.150
Scioto (Harrisonville), in sandstone foundation under southwest corner of Knights of Pythias two-story building, west side of street; bronze tablet stamped "654 I"	656.793
Scioto, 3.8 miles northeast of, on Jackson Pike, at southeast corner of T road southeast, about 0.2 mile west of White schoolhouse (district 10), Madison Township; iron post stamped "728"	727.613
Scioto, 4.8 miles northeast of, T road southwest, in southwest corner of top of stone; chiseled cross	589.90
Massie, near, 7.4 miles northeast of Scioto, 120 feet northwest of schoolhouse (district 12), east side of road, 75 feet higher than main road, in sandstone ledge of hillside; bronze tablet stamped "678 I"	679.856

Bench marks near Lucasville.

Davis, 0.09 mile south of station, on southeast corner of south abutment of railroad bridge over highway, in stone; chiseled circular mark	564.7

	Feet
Lucasville, about 600 feet north of Norfolk & Western Ry. station, at corner of flour mill; iron post stamped "Prim. Trav. Sta. No. 28, 1904, 559"	558.629

GREENUP QUADRANGLE.

Portsmouth north along Norfolk & Western Ry.

Portsmouth, southwest corner of stone step, south side of Norfolk & Western Ry. station; chiseled square	534.69
Portsmouth, 1.7 miles northwest of, 360 feet northwest of Vera Tower, on east end of south abutment of Norfolk & Western Ry. trestle approach to bridge over Scioto River; chiseled square	535.60

Portsmouth east along Baltimore & Ohio Southwestern R. R.

Portsmouth, Norfolk & Western Ry. and Baltimore & Ohio Southwestern R. R. crossing; top of rail	530.9
Portsmouth, northeast corner of Tracy Park; iron post stamped "Prim. Trav. Sta. No. 27, 1910, 532"	531.683
Portsmouth, east end of door sill of main entrance, north side of station building; chiseled square with cross on it (Norfolk & Western Ry. bench mark)	534.74

OTWAY QUADRANGLE.

Rushtown along Norfolk & Western Ry. to Rarden.

Rushtown, 600 feet north of station, northwest corner of road crossing, in front of George Russel's residence; iron post stamped "539"	539.265
McDermott, 120 feet east of station, 15 feet west of road at crossing; iron post stamped "575"	574.609
Arion, 35 feet south of railroad, opposite station, 15 feet east of road, 1 foot west of post-office building; iron post stamped "587"	587.091
Henley, road crossing at station, 30 feet north of railroad and 10 feet east of road; iron post stamped "574"	574.255
Otway, north side of station platform, 20 feet west of station; iron post stamped "586"	585.740
Young, 0.3 mile northwest of, about 150 feet west of road crossing, 5 feet south of highway; iron post stamped "598"	598.392
Rarden, 175 feet west of station, north of track, 75 feet west of creek, on north side of right of way line; iron post stamped "613"	612.755

Wakefield west along public roads via Camp and Ladd to Duke, thence south to Rarden.

Wakefield, a little north of town, 2.2 miles south of Sargents, on west side of north abutment of railroad bridge over creek; aluminum tablet stamped "551"	550.931
Coopersville, 2.2 miles west of, northeast corner of T road north, 50 feet from center of road; iron post stamped "582"	581.627
Camp, 1.2 miles west of, southwest corner of crossroads, near fence corner, 50 feet west of road north; iron post stamped "Prim. Trav. Sta. No. 80, 1909, OHIO, 665"	665.194
Camp, 2.7 miles west of, top of stone on north side of road; chiseled cross painted "779.3"	779.26
Ladd, southwest corner of crossroads, 30 feet from center of roads; iron post stamped "1105"	1,104.770

	Feet.
Duke, 200 feet east of road forks in center of town, south side of road opposite schoolhouse; iron post stamped "1237"	1, 237. 149
Duke, 3.2 miles southwest of, west of road on south side of large hill, in base of stump; spike painted "1107.5"	1, 107. 47
Duke, 3.8 miles southwest of, 2.7 miles northwest of Rarden, at foot of Wallace Hill, 250 feet northwest of Clark Foster's residence, 20 feet west of center of road; iron post stamped "705"	705. 190

Baptist Church on Pond Creek north along public road via Arion and Crabtree to Camp.

Pond Creek Baptist Church, first road crossing west of, T road at Pond Creek, about 20 feet south of road running east-west and 10 feet west of road running north-south; iron post stamped "725"	724. 772
Pond Creek, second road fork west of Baptist Church, in root of sycamore tree; spike marked "781.111"	781. 01
Arion, 2.6 miles south of, road crossing at Flats school, on Galena-Portsmouth Pike, in corner of field belonging to Frank Johnley, south of road running east-west and east of road running north-south; iron post stamped "722"	721. 387
Arion, 1.3 miles south of, east of road on summit of hill, 679 feet north of residence belonging to James Castor, in root of small black oak tree; spike painted "925.128"	924. 97
Arion, 1 mile north of, at road crossing, about 30 feet west of road running north-south and 6 feet south of road running east-west, on stone; chiseled square painted "703.004"	702. 84
Arion, 2.4 miles north of, on east side of road, 589 feet north of residence and about halfway down large hill, on rock; chisel mark painted "764.005"	763. 85
Crabtree post office, 0.9 mile north of, at Y road; iron post stamped "767"	767. 028
Sedan, 1 mile south of, west of road and about 20 feet north of mail box at lane, on small rock; chiseled square painted "824.490"	824. 39
Sedan, 0.4 mile west of, at T road, north side of road running east-west and about 15 feet west of road running north-south; iron post stamped "801"	800. 908

PORTSMOUTH QUADRANGLE.

Portsmouth along Ohio River to McGaw.

Portsmouth, southeast corner of post-office building, in first course of foundation, 1 foot above ground; chiseled square (U. S. Army Engineers' bench mark)	535. 129
Portsmouth, 3.2 miles southwest of, at northwest corner of T road north, about 100 feet west of stone arch bridge over Carys Run; iron post stamped "516"	516. 102
Dennis, northeast corner of road forks, near telephone pole and fence; iron post stamped "529"	529. 07
Pondrum, southwest corner of T road northwest, 40 feet west of center of T road; iron post stamped "Prim. Trav. Sta. No. 8, 1910, 522"	522. 461
Pondrum, 2.1 miles west of, north side of road, 40 feet from center of lane to south; iron post stamped "528"	52[illegible]
Pondrum, 6 miles west of, about 3 miles east of Buena Vista, on south side of road near telephone pole, at Elm Tree schoolhouse; iron post stamped "566"	

County infirmary at Alexandria north along road.

	Feet.
Alexandria, T road at Scioto County Infirmary; iron post stamped "516"	516.102
Carys Run schoolhouse, on stone abutment of culvert; chiseled square painted "608.451"	608.42
Carys Run, about 200 feet south of residence of Charles L. Simon, east of highway; iron post stamped "692"	691.657

Turkey Creek along road to Friendship.

Union Church, northeast corner of; iron post stamped "659"	658.929

Pink along road to McGaw.

Pink, 5 miles southeast of, road forks at mouth of Brushy Fork, east of road, 20 feet northwest of apple tree; iron post stamped "882"	882.095
Pink, 6 miles southeast of, east of road on creek bank, driven in root of small sycamore tree 1 foot in diameter; head of spike painted "828.2"	828.23
McGaw, 3.2 miles northwest of, west of road, on top of stone; chisel mark painted "718.0"	717.98
McGaw, 3.2 miles northwest of, on upper Twin Creek, in front of Clay Cooper's residence, west of road, 20 feet north of lane; iron post stamped "721"	720.726
McGaw, 1.1 miles north of, east of road, 150 feet north of bend in road, in front of John Hodge's residence, on large stone; chiseled cross painted "573.4"	573.35

PEEBLES QUADRANGLE.

Rarden to point 2 miles west of Lawshe along Norfolk & Western Ry.

Rarden, 2.1 miles west of, milepost "C 80-P 27," side of track, on top of stone culvert; chiseled square painted "616.2"	616.31
Jaybird (Mineral Springs station), southeast corner of road crossing at station, 5 feet southeast of warning post; iron post stamped "629"	629.061
Peebles, 2.4 miles northeast of, 15 feet north of railroad, 10 feet east of road, at marle-bank switch road crossing; iron post stamped "760"	760.315
Peebles, 500 feet east of station, 25 feet east of center of road and 10 feet north of railroad at road crossing; iron post stamped "813"	813.480
Lawshe, 250 feet east of station, 75 feet west of road and 20 feet south of railroad at road crossing; iron post stamped "648"	648.310

Jaybird via Mineral Springs, Wamsley, and Blue Creek to Pink.

Mineral Springs, 1.3 miles northeast of, south of road at bend, north side of hill near bottom, on top of stone; chisel mark painted "868.3"	868.47
Mineral Springs, 1 mile northeast of, in northwest corner of road forks on top of hill, at private road northwest; iron post stamped "1127"	1,127.269
Mineral Springs, 300 feet north of Mineral Springs Hotel, 20 feet east of forks, south end of west stone abutment of bridge in top; chisel mark painted "758.780"	758.95
Mineral Springs, 2.1 miles southeast of, southeast corner of T road south, 30 feet east of forks, south of road, opposite Antioch Church and school; iron post stamped "671"	671.208

	Feet.
Mineral Springs, 2.6 miles southeast of, on stone south of road; chisel mark painted "640"	640.10
Wamsley, 1.3 miles southwest of, west of road, 20 feet north of McClellan Jones's store, 150 feet north of T road west; iron post stamped "619"	618.934
Blue Creek, W. S. Newman's store, 15 feet north of road forks, east of road and at T road east; iron post stamped "641"	641.679
Pink, 75 feet east of stone, north of road, in fence corner; iron post stamped "899 Prim. Trav. Sta. No. 10, 1910"	898.683
Pink, 0.2 mile east of, 50 feet northwest of Kidder's store, in southwest corner of forks, on stone; chiseled mark painted "874.8"	875.00

Wamsley via Cedar Mills to West Union.

Cedar Mills, T road, Peebles and Wamsley pikes, north side of road, opposite fork; iron post stamped "564"	564.509
Cedar Mills, 2.3 miles west of, northeast corner of T road, east, in root of hackberry tree; nail head painted "535.600"	536.03
Cedar Mills, 3.6 miles west of, at road crossing, in root of red oak at northeast corner; nail head painted "606.828"	607.33
Cedar Mills, 5.3 miles west of, opposite Blue Creek Pike, near telephone pole; iron post stamped "905"	905.590

Peebles via Fawcett and Cedar Mills to Tulip.

Peebles, 2.7 miles southeast of, 0.25 mile north of school building, on northwest corner of stone abutment of culvert at T road; chiseled circle	827.18
Peebles, 3.1 miles southeast of, east of pike and about 0.25 mile south of school building, on rock at T road, east side of pike; chiseled circle	825.80
Fawcett, 2.3 miles north of, 40 feet south of pike at T road, on northwest corner of stone abutment of building; chiseled circle	804.17
Fawcett, about 30 feet west of store, near telephone pole at road crossing; iron post stamped "837"	836.870
Cedar Mills, 1 mile north of, on east side of highway, in front of Cedar school building, in root of large white oak tree; spike	787.08
Cedar Mills, 3.6 miles south of, northeast corner of stone abutment of iron bridge on pike, west of Linx store; chiseled circle	716.58
Tulip, 3.1 miles north of, west of highway at road forks, about 0.25 mile north of house, mark on limestone rock; chiseled circle	765.58

Blue Creek to Tulip.

Blue Creek, 3.1 miles west of, southwest corner of roads, in base of sycamore tree; nail head	686.24
Blue Creek, 5.9 miles west of, on high hill, junction with lane passing through farm to road leading to Tulip, in base of pignut tree at northwest corner; top of nail head	1,150.79

WEST UNION QUADRANGLE.

Mayhill via Tranquility and Unity to West Union and Beasleys Fork.

Mayhill, 1.7 miles southwest of, about 15 feet north of mail box at T road, in front of W. S. Moore's residence, on stone in pike; chiseled circle	1,027.24

	Feet.
Tranquility, 2.4 miles north of, south end of stone culvert at road crossing; chisel mark	914.37
Tranquility, west end of culvert about 50 feet north of store; iron post stamped "770"	770.218
Tranquility, 1.8 miles south of, in middle of highway at T road, on limestone; chisel mark (circle)	817.34
Lawshe, 3.1 miles west of, road crossing under Norfolk & Western Ry., 50 feet south of railroad and 10 feet west of road; iron post stamped "672"	671.689
Lawshe, 2.9 miles west of, bridge 2038, at milepost P 42-C 65, south end of west abutment, 2½ feet below track; chiseled square (Norfolk & Western bench mark)	671.65
Unity, northeast corner of crossroads, 30 feet northeast of center of crossroads; iron post stamped "958"	958.684
West Union, 3 miles northwest of, on Unity Pike, 30 feet northeast of center of road forks; iron post stamped "836"	836.171
West Union, southeast corner of Main Street (Wamsley Pike) and East Street (Wrightsville Pike); iron post stamped "956"	956.565
West Union, 2.4 miles south of, on Wrightsville Pike, 30 feet south of small iron bridge over Beasleys Fork, southeast corner of road forks, 1 foot from retaining wall, at T road east; iron post stamped "Prim. Trav. Sta. No. 14, 1910 648"	648.878

Emerald south to Decatur and Maddox, thence northeast to West Union.

Emerald, 2.5 miles southwest of, in middle of highway at road crossing, about 0.25 mile south of Wilson school building, on limestone rock; chisel mark (circle)	1,023.11
Emerald, 4.2 miles southwest of, at T road, north of highway in front of Louis Julia's residence; spike in root of wild cherry tree	1,021.55
Emerald, 5.7 miles southwest of, 20 feet north of Norfolk & Western Ry. track and 15 feet west of highway at railroad crossing; iron post stamped "1054"	1,054.032
Emerald, 7.3 miles southwest of, at T road, in front of J. L. Watson's residence, about 3 miles northeast of Carlisle, on limestone rock near mail box; chiseled circular mark	975.70
Emerald, 7.8 miles southwest of, at T road, at base of small white oak tree standing in middle of road forks near old cemetery, on rock; chiseled circle	1,017.84
Emerald, 12.5 miles south of, on west side of pike at Y road, about 0.25 mile north of Baird school, on limestone rock; chiseled circular mark	912.87
Emerald, 13 miles south of, at Baird school on Russellville Pike, about 2.5 miles east of Russellville, in corner of schoolhouse lot; iron post stamped "Prim. Trav. Sta. No. 22, 947"	946.984
Decatur, 4.2 miles northwest of, 2 miles east of Russelville, in coping at northeast corner of covered bridge over Eagle Creek; bolthead	814.22
Decatur, at street crossing, in middle of village; iron post stamped "924"	924.320
Decatur, 1.7 miles south of, on Decatur and Aberdeen Pike, in coping at northwest corner of covered bridge over Eagle Creek at road forks west of old mill; bolthead	653.38
Maddox, 1.4 miles north of, east end of stone culvert near road forks at Suck Run school building; chiseled circular mark	731.79

	Feet.
Maddox, about 60 feet east of store on south side of pike; iron post stamped "963"	963.110
Bentonville, about 60 feet east of road crossing, in center of town, west of pike, back of telephone pole; iron post stamped "914"	914.544
Bentonville, 1.3 miles northeast of, 200 feet east of Riffle's residence at North Liberty Pike, at base of telephone pole, on limestone rock; chiseled circular mark	882.13

GEORGETOWN QUADRANGLE.

Sardinia via Biehn, Russellville, and Red Oak to Ripley.

Sardinia, about 3 miles east of, 0.8 mile east of Five Points or Biehn post office, Norfolk & Western Ry. milepost "C 50+2467 ft.", on southwest corner of cover stone, south end of stone box culvert; cross cut	998.964
Sardinia, 2.5 miles east of, at Five Points (Biehn post office), crossroads at; iron post stamped "1000"	1,000.984
Carlisle, about 1.5 miles northwest of, on Arnheim Pike, in northwest corner of T road north; iron post stamped "1045"	1,046.252
Russellville, east side of public square, 2 feet north of jail and voting house, 35 feet west of Ripley Pike; iron post stamped "975"	975.473
Russellville, 2.8 miles south of, northeast corner of crossroads, 25 feet from center of crossroads; iron post stamped "927"	928.002
Ripley, 2.9 miles northeast of, southeast corner of T road east, 10 feet north of east end of small wooden bridge; iron post stamped "602"	603.039
Ripley, 2 miles north of, T road west at schoolhouse, northwest corner of road forks, on large stone; chiseled cross marked "543.7"	544.75
Ripley, 1.3 miles north of, in center of road forks, on top of stone; chiseled cross marked "536.0"	537.02

MAYSVILLE QUADRANGLE.

Ripley along Ohio River to Aberdeen.

Ripley, southwest corner of Main and Second Streets, 8 feet west of corner; chiseled square; curbing marked "505.439"	506.42
Ripley, 40 feet west of west end of steel bridge over Red Oak Creek, on East Second Street, 15 feet south of center of road; iron post stamped "501"	501.917
Ripley, 6 miles southeast of, 20 feet east from center of road forks, on Threemile Creek; iron post stamped "514"	515.119
Aberdeen, 0.5 mile north of, on Maysville and Zanesville Pike, at fork of road, 100 feet east of large steel bridge over Fishing Gut Creek, northwest corner of road forks; iron post stamped "Prim. Trav. Sta. No. 20, 1910, 521"	522.055
Maysville, Ky., southwest corner of Court and Second streets, Pearce & Wallingford building, occupied by State National Bank of Maysville, on water table on northwest corner about 4.5 feet above sidewalk; chiseled square marked "U.S.□B.M." (This bench mark is on checked spur line from Aberdeen)	524.498

MANCHESTER QUADRANGLE.

Aberdeen via Manchester to Wrightsville.

Aberdeen, 4.4 miles east of, 160 feet east of small iron bridge over Little Threemile Creek, in northwest corner of crossroads, on top of stone; chiseled cross marked "511.55"	

	Feet.
Aberdeen, 5.8 miles east of, on Manchester Pike, 35 feet southeast of center of forks, southeast corner of T road south to Ohio River; iron post stamped "554"	555.044
Manchester, 4.2 miles west of, 10 feet south of forks, on south side of road at T road north up hollow; iron post stamped "Prim. Trav. Sta. No. 19, 1910 513"	514.127
Manchester, southwest corner of Manchester and Bentonville Pike and Second Street, in northeast corner of fence around pump, opposite Presbyterian cemetery; iron post stamped "510"	511.226
Manchester, 0.7 mile east of, on Manchester and Rome Pike, 150 feet west of bend to northeast in road, 2 feet east of telephone pole south of road; iron post stamped "519"	519.499
Wrightsville, southeast corner of crossing of Manchester and Rome and Wrightsville and West Union pikes; iron post stamped "Prim. Trav. Sta. No. 17, 1910 533"	533.370

Beasleys Fork to Wrightsville.

Beasleys Fork post office, at road forks, 200 feet east of large iron bridge over Beasleys Fork, 50 feet west of store and 35 feet southwest of center of road forks; iron post stamped "584"	584.471
Wrightsville, 0.60 mile west of, on Kentucky bank of Ohio River, 60 feet west of Gilpins Run, 25 feet south of Ohio River, in base of 6-inch willow tree; log screw	473.91

VANCEBURG QUADRANGLE.

Tulip to Rome (Stout post office).

Tulip, 0.5 mile south of, on west side of highway at T road, in front of Lasty Spire's residence, on limestone rock; chiseled circle	784.03
Tulip, 0.7 mile south of, at T road; iron post stamped "808"	808.155
Tulip, 1.8 miles south of, west of highway at road forks, foot of Rodgers Hill, on stone; chiseled circle	798.76
Rome, 3.1 miles north of, west of road, in front of school building, district 2, Green Township, Adams County, in root of large elm tree; spike	564.88
Rome, 0.8 mile north of, west end of stone culvert under pike at road forks in front of W. Tracy's residence; chiseled circular mark	513.75

Bench mark near Buena Vista.

Buena Vista, 0.5 mile east of, at northwest corner of crossroads, 30 feet west of center of crossroads; iron post stamped "Prim. Trav. Sta. No. 9, 1910 OHIO 515"	515.087

Wrightsville via Rome to Buena Vista.

Wrightsville, 3.6 miles east of, 0.5 mile northwest of large steel bridge over Ohio Brush Creek, northeast corner of road forks; iron post stamped "544"	544.810
Rome, crossing of Main and Second streets, 50 feet southeast of center of crossroads; iron post stamped "Prim. Trav. Sta. No. 16, 1910, 524"	524.737
Rome, 4.8 miles east of, near T road north and private road south, center of road fork made by road north; iron post stamped "579"	580.21
Sandy Springs, opposite Vanceburg, Ky., in southeast corner of T road south to Ohio River; spike in root of hickory tree	515.61

	Feet.
Buena Vista, 1 mile west of, on north wing of east abutment at northeast corner of small iron bridge over Rock Run; chiseled cross	513.60

Tulip to Beasleys Fork.

Tulip, 2.8 miles southwest of, at Wagners Ripples, south of highway at Y road in front of old mill; spike in root of large sycamore tree	516.61
Beasleys Fork, 4.3 miles east of, southwest corner of stone abutment of iron bridge over Black Run, about 400 feet east of road forks; chiseled circle	509.93
Beasleys Fork, 3 miles east of, Cedar College, at road forks; iron post stamped "550"	550.678

Sandy Springs to Vanceburg (checked spur line).

Vanceburg, Ky., on south side of soldiers' monument in courthouse yard; chiseled square (U. S. Army engineer's elevation 528.242)	527.742

BAINBRIDGE QUADRANGLE.

Duke via Poplar Grove to Mayhill.

Duke, 2.3 miles northwest of, north of highway opposite lane leading to W. V. Tompson's residence, on stone marking corner of Scioto and Pike Counties; chiseled circle	1,239.91
Duke, 3.3 miles northwest of, at road crossing, 30 feet west of store belonging to Thomas Grooms; iron post stamped "1227"	1,227.178
Poplar Grove, 5.9 miles northwest of Duke, 40 feet north of store; iron post stamped "1135"	1,134.652
Poplar Grove, 5 miles west of, east of highway about 50 feet south of east-west road; iron post stamped "781"	781.000
Louden, 2.7 miles east of, north side of pike at T road, about 500 feet west of Anders school building, spike in root of large oak tree	772.87
Louden, about 20 feet from northwest corner of store on north side of pike near telephone pole; iron post stamped "782"	782.310
Louden, 1.6 miles west of, on stone abutment at southeast corner of iron bridge over Flat Run; chiseled circle	729.61

HILLSBORO QUADRANGLE.

Mayhill to Emerald.

Mayhill, at road crossing; iron post stamped "Prim.Trav.Sta.No. 82, OHIO 1909"	1,013.396
Mayhill, 0.3 mile south of, east of pike, at road forks; nail in root of poplar tree	1,014.84
Mayhill, 0.8 mile west of, on north side of highway at road crossing, about 40 feet north of large oak tree, on limestone rock; chiseled circle	846.93
Mayhill, 3.4 miles west of; spike in root of large oak tree at road forks	940.61
Mayhill, 5.4 miles west of, at Buck Run, east of highway at T road, about 100 feet south of H. N. Barrackman's house; iron post stamped "932"	932.427
Emerald, 4.3 miles east of, at T road, in middle of highway, on limestone rock; chiseled circle	949.01
Emerald, 2.8 miles northeast of, 10 feet south of highway east-west and 40 feet west of highway north-south, at road crossing, 300 feet north of Highland County line, on limestone rock; chiseled circle	980.15

	Feet.
Emerald, 0.6 mile east of, east of highway where road turns squarely to north; iron post stamped "Prim. Trav. Sta. No. 85 977"	976.950

Continental, Covington, Delphos, Lima, Loramie, Sidney, Spencerville, and Troy Quadrangles.

ALLEN, AUGLAIZE, DARKE, MIAMI, PUTNAM, SHELBY, AND VAN WERT COUNTIES.

The elevations in the following list are based upon the Coast and Geodetic Survey precise level line from Cincinnati to Toledo.

The leveling was done in 1909 by H. B. Hoel.

DELPHOS QUADRANGLE.

Rimer along Northern Ohio Ry. to Delphos, thence north to Muntanna along Toledo, St. Louis & Western R. R.

	Feet.
Rushmore, southeast corner of yard of Herbert Thurston, 40 feet north of railroad crossing; iron post stamped "760"	759.511
Rushmore, 2.4 miles west of, at railroad crossing, in right of way, 40 feet west of road, 40 feet north of railroad; iron post stamped "765"	764.464
Fort Jennings, 0.7 mile south of, at railroad crossing, 30 feet east of crossing, on right of way; iron post stamped "755"	754.423
Fort Jennings, railroad crossing at station; top of rail, painted "753.83"	753.6
Douglass, 0.8 mile south of, at railroad crossing, 30 feet east of Toledo, St. Louis & Western R. R. track, 30 feet north of road, on right of way; iron post stamped "746"	745.266
Douglass, railroad crossing at station; top of rail, painted "744.52"	744.2
Muntanna station, at railroad crossing, 40 feet west of, 35 feet north of highway, on right of way; iron post stamped "729"	728.839

Delphos west 3 miles along Pennsylvania R. R., thence north along highway to Roselms.

Delphos, in northeast corner of yard of tower house at crossing of Pennsylvania R. R. and Toledo, St. Louis & Western R. R.; iron post stamped "780"	779.645
Delphos, near; railroad bench mark (Pennsylvania R. R. levels, adjustment of 1903, give elevation as 781.355)	781.299
Delphos, 3.2 miles west of, 30 feet west of road, 10 feet south of railroad, on right of way; iron post stamped "777"	776.388
Seamersville, 3 miles south of, in southwest corner of northeast field at crossroads; iron post stamped "763"	762.836
Seamersville, in southwest corner of yard of John Dunlap at crossroads; iron post stamped "745"	745.134
Roselms, 3 miles south of, at crossroads, in southwest corner of yard of Elm Grove schoolhouse, subdistrict 1, Jackson township; iron post stamped "733 OHIO"	733.107

Middlepoint west 2 miles along Pennsylvania R. R., thence north to point 3 miles south of Grove Hill along highway.

Middlepoint, west end of plank at railroad crossing at station; top of such rail, painted "782.3"	782.0
Middlepoint, 0.5 mile west of, at railroad crossing, on right of way, 50 feet west of road, 10 feet south of railroad; iron post stamped "785"	784.754

	Feet.
Van Wert County Infirmary, 0.25 mile west of, southeast corner of crossroads; iron post stamped "777 Prim. Trav. Sta. No. 11"	777.213
Middlepoint, 2.5 miles west by 5 miles north of, northeast corner of crossroads; iron post stamped "752"	751.575
Grove Hill, 3 miles south by 1 mile west of, northeast corner of crossroads; iron post stamped "736"	735.653

Delphos south along Cincinnati, Hamilton & Dayton Ry. to Southworth.

Delphos, 2.9 miles south of, at railroad crossing, 30 feet south of highway and 30 feet west of railroad, on right of way; iron post stamped "791"	790.414
Southworth post office, north end of plank at railroad crossing; top of east rail, painted "814.89"	814.7
Southworth post office, 0.4 mile south of, northwest corner, north side of T road west, 50 feet west of canal, inside fence; iron post stamped "813"	813.118

Middlepoint south along highway to point 2.5 miles south of Venedocia.

Middlepoint, 0.5 mile west by 2.8 miles south of, at northwest corner of T road; iron post stamped "791"	790.708
Venedocia, 1 mile south of, at southeast corner of T road east; iron post stamped "804"	803.998

Venedocia east to Southworth.

Landeck, 2 miles south by 0.5 mile west of, southeast corner of crossroads; iron post stamped "813"	812.318

SPENCERVILLE QUADRANGLE.

Spencerville east along Erie R. R. to Kempton.

Spencerville, intersection of Cincinnati, Hamilton & Dayton R. R. and Erie R. R., 30 feet west of the former and 80 feet north of the latter, on right of way; iron post stamped "827"	827.127
Conant post office, 30 feet west of road, 60 feet south of railroad, at railroad crossing, on right of way; iron post stamped "828"	828.034

Spencerville west 6.6 miles along Erie R. R., thence south to St. Marys.

Spencerville, in front of station; top of rail	828.0
Spencerville, 3 miles west of, 50 feet north of railroad, near crossing, 40 feet west of road, on right of way; iron post stamped "824"	823.366
Converse, at west end of plank at railroad crossing; top of north rail, painted "827.40"	827.0
Venedocia, 3.5 miles south of, 60 feet north of Erie R. R., at crossing, 35 feet west of road, on right of way; iron post stamped "816"	816.126
Kossuth, 3 miles north by 4.5 miles west of, southwest corner of crossroads on county line; iron post stamped "843"	842.423
Mendon, 3.8 miles east of, southeast corner of crossroads; iron post stamped "829"	828.508
St. Marys, 2 miles west by 6.5 miles north of, southeast corner of crossroads; iron post stamped "833"	832.551
St. Marys, 3.5 miles west by 3.5 miles north of, northeast corner of crossroads; iron post stamped "852"	851.897

	Feet.
St. Marys, 3 miles west of, 30 feet west of highway and 10 feet south of railroad, near crossing, on right of way; iron post stamped "903"	902.765
St. Marys, in front of Lake Erie & Western R. R. station; top of rail	870.2
St. Marys, 315 feet east of Lake Erie & Western R. R. station, 115 feet west of street, 28.4 feet south of south rail of main track, at railroad crossing of Wayne Street, on right of way; iron post stamped "871"	870.988

Spencerville south via Kossuth to St. Marys, thence east to point 2 miles beyond Moulton.

Kossuth, 1.1 miles northwest of, west side of north-south road, at T road east; iron post stamped "842"	841.576
St. Marys, 6 miles north of, east side of north-south road, at T road west; iron post stamped "828"	827.676
St. Marys, 3 miles north of, at southwest corner of crossroads; iron post stamped "859"	858.975
Moulton, 1.1 miles west of, 15 feet south of railroad at crossing, 40 feet west of road, on right of way; iron post stamped "906"	905.447
Moulton, 2 miles east of, 30 feet north of railroad at crossing, 30 feet east of highway, on right of way; iron post stamped "882"	882.108

Point 4 miles southeast of Moulton via Moulton to Conant.

Moulton, in front of station; top of rail	896.7
Moulton, 2.25 miles north of, northwest corner of crossroads; iron post stamped "873"	873.430
Moulton, 5.25 miles north of, southeast corner of T road south; iron post stamped "848"	848.107
Conant, 3.5 miles south of, southeast corner of T road east; iron post stamped "834"	833.887

LORAMIE QUADRANGLE.

Point 2.5 miles south of St. Marys south via Minster and Loramie to Huffman schoolhouse.

New Bremen, southeast corner of Zion (Reformed) Church, midway between steps leading to south and west door of church; iron post stamped "941"	941.103
Minster, in yard in rear of Sommer Hotel, 15 feet south of south face of building and 4 feet west of sidewalk, inside fence; iron post stamped "968"	967.718
Loramie, at north end of west abutment of iron bridge over canal and 60 feet southeast of V. Gaier's store; iron post stamped "959"	958.894
Newport, 1.5 miles north of, on east side of north-south road, at T road west, 100 feet northwest of brick schoolhouse, district 4; iron post stamped "1006"	1,005.782
Newport, 1.25 miles south of, at southeast corner of diagonal road southeast; iron post stamped "953"	953.066

Point 5 miles west of Swanders west via Loramie to Yorkshire.

Loramie, 0.5 mile south by 4.5 miles east of, 50 feet south of and in front of residence of John Roman; iron post stamped "1000"	1,000.204

Feet.

Loramie, 0.5 mile south by 2 miles east of, at southeast corner of crossroads; iron post stamped "972" ---- 972.299

Loramie, 3 miles west of, at Darke-Shelby County line, northeast corner of crossroads; iron post stamped "955" ---- 955.110

Bench mark 3 miles east of New Knoxville.

New Knoxville, 3 miles east by 1 mile south of, on Shelby-Auglaize County line, at southwest corner of crossroads; iron post stamped "Prim. Trav. Sta. No. 6 928" ---- 928.344

North Houston along Cleveland, Cincinnati, Chicago & St. Louis Ry. to Hardin.

Houston, in front of station; top of rail ---- 962.1

Dawson, at station, in southwest corner of yard of residence of E. J. Griffis, 15 feet north of railroad and 40 feet west of station, at railroad crossing; iron post stamped "943" ---- 943.161

Hardin Station, 1.5 miles east of, 30 feet south of railroad and 25 feet west of road, at railroad crossing, on right of way; iron post stamped "989" ---- 988.874

Point 2 miles south of Kettlersville west to Minster.

Minster, 1 mile north by 4 miles east of, north side of east-west road at T road south; iron post stamped "974" ---- 974.450

Point 2 miles northwest of Chickasaw east along highway to Botkins.

Chickasaw, 2 miles north by 0.8 mile east of, in concrete bridge seat at northwest corner of small iron bridge; aluminum tablet stamped "899 ADJ 1905" ---- 898.712

New Bremen, 3 miles north of, sec. 34, T. 6 S., R. 4 E., on traction line, at southeast corner of crossroads, in west face at northwest corner of brick schoolhouse; aluminum tablet stamped "902 ADJ 1905" ---- 901.558

New Knoxville, 2 miles southwest of, north of center of sec. 36, T. 6 S., R. 4 E., in north face of northeast corner of Berghorn schoolhouse (subdistrict 2); aluminum tablet stamped "918 ADJ 1905" ---- 917.560

Botkins, 5 miles west of, southeast corner of sec. 33, T. 6 S., R. 5 E., at northwest corner of diagonal road to northwest, east side at southeast corner of schoolhouse, in stone under window; aluminum tablet stamped "944 ADJ 1905" ---- 943.731

Botkins, 3 miles west of, at southwest corner of sec. 36, T. 6 S., R. 5 E., northeast corner of T road north, at southeast corner of schoolhouse, east face, in stone under window; aluminum tablet stamped "965 ADJ 1905" ---- 964.303

Chickasaw south along Cincinnati, Hamilton & Dayton Ry. to Yorkshire.

Chickasaw, southwest corner of sec. 11, T. 7 S., R. 3 E., in southeast corner of store and dwelling of H. Gast, south face, in water table; aluminum tablet stamped "947 ADJ 1905" ---- 946.731

Maria Stein, northwest corner of sec. 26, T. 7 S., R. 3 E., west face, about 10 feet from northwest corner, of Myers & Patty's grain elevator; aluminum tablet stamped "974 ADJ 1905" ---- 973.710

Yorkshire, northeast corner of sec. 13, T. 12 N., R. 3 E., at southwest corner of T road south, in north face at northwest corner of small brick store building; aluminum tablet stamped "988 ADJ 1905" ---

TROY QUADRANGLE.

Troy southwest 1.5 miles.

	Feet.
Troy, 1.8 miles southwest of, extreme southeast corner of section 30, Concord Township, Miami County, northwest corner of crossroads; iron post stamped "888"	888.128

Lockington north along highway to Newburn.

Newburn, at northeast corner of T road east; iron post stamped "960"	960.337

SIDNEY QUADRANGLE.

Point 4 miles east of New Knoxville south along highway to Hardin, thence to Sidney.

Kettlersville, 1 mile east of, southwest corner of T road south; iron post stamped "979"	978.843
McCartysville, 1 mile east of, northwest corner of crossroads; iron post stamped "980"	980.106
Hardin, 4 miles north of village, northwest corner of crossroads; iron post stamped "990"	990.428
Hardin, 1 mile north of village, northwest corner of crossroads; iron post stamped "960"	959.422
Hardin, 2 miles east of station, southwest corner of T road east, 60 feet north of railroad crossing; iron post stamped "1015"	1,015.219
Spafford, in front of power house; top of rail	1,028.2

Swanders southwest 5 miles.

Swanders, in front of station; top of rail	1,018.3
Swanders, 1 mile south by 2 miles west of, at southwest corner of crossroads; iron post stamped "1028"	1,028.009

COVINGTON QUADRANGLE.

Versailles northeast along Cleveland, Cincinnati, Chicago & St. Louis Ry. to point 1 mile east of Russia.

Versailles, east edge of sec. 24, T. 11 N., R. 3 E., west part of town, southwest corner of Cleveland, Cincinnati, Chicago & St. Louis Ry. bridge over Indian Creek, in back wall; aluminum tablet stamped "969 ADJ 1905"	968.659
Versailles, northwest corner of tower house, at intersection of Cleveland, Cincinnati, Chicago & St. Louis Ry. and Cincinnati, Hamilton & Dayton Ry., inside painted ring on concrete base of bell crank of interlock switch; chiseled square painted "980.66"	980.46
Versailles, 3 miles east of, 40 feet south of railroad and 25 feet west of public road, near railroad crossing, at Darke-Shelby County line, on right of way; iron post stamped "978"	977.917
Russia, 1.5 miles east of, at railroad crossing, southwest corner of school yard at Huffman schoolhouse, 60 feet north of railroad and 25 feet east of road; iron post stamped "969"	969.204

Versailles along Cincinnati, Hamilton & Dayton Ry. to Covington, thence via Pittsburg, Cincinnati, Chicago & St. Louis Ry. to Piqua.

Bloomer post office, 25 feet east of road, 20 feet north of railroad, near crossing, at southwest corner of yard of residence of W. W. Sands, on right of way; iron post stamped "1021"	1,021.042

	Feet.
Abe, at south end of plank at railroad crossing; top of west rail painted "975.83"	975.6
Abe, 0.5 mile south of, at railroad crossing, 10 feet west of railroad, 25 feet north of public highway; iron post stamped "965"	964.385
Covington, in public school yard, on corner of Pearl and Maple Streets, 15 feet south of west entrance to school building; iron post stamped "933"	932.755
Covington, 3 miles east of, 30 feet north of railroad at crossing, 30 feet west of public highway, on right of way; iron post stamped "972"	971.807

Bloomer north along highway to county line, thence east to Lockington.

Bloomer, 0.6 mile north by 3 miles east of, northeast corner of crossroads; iron post stamped "981"	980.863
Bloomer, 0.6 mile north by 6 miles east of, 25 feet north of east-west road, at T road south, in southeast corner of field; iron post stamped "984"	983.729
Lockington, 0.5 mile south by 1 mile west of, at southwest corner of crossroads, on large rock, inside painted ring; chiseled square, painted "910.58"	910.26
Lockington, 0.3 mile west of, on east side of north-south road, at T road east; iron post stamped "884"	883.848

Covington west along Pennsylvania R. R. via Bradford to Oakland.

Bradford, 50 feet west of telegraph office, 25 feet north of Logansport division railroad track in railroad yard; iron post stamped "992"	991.849

Bradford south along highway to Laura.

Bradford, 2.5 miles south of, southwest corner of Newberry Township, Miama County, southwest corner of yard of schoolhouse 14; iron post stamped "982"	981.703
Painter Creek, 2 miles east by 1 mile north of, northwest corner of crossroads, 50 feet east of residence of J. E. Hollacher, southwest border of sec. 16, T. 8 N., R. 4 E.; iron post stamped "996"	996.089
Painter Creek, 2 miles east by 1 mile south of, at northwest corner of T road north, center of S. W. ¼ sec. 28, T. 8 N., R. 4 E.; iron post stamped "1005"	1,005.416

Covington south along Cincinnati, Hamilton & Dayton Ry. to Ludlow Falls.

Covington, 2.5 miles south of, near railroad crossing, 20 feet east of public highway, 30 feet south of railroad; iron post stamped "925"	924.541
Pleasant Hill, in front of station; top of east rail	907.4
Pleasant Hill, 1 mile south of, at railroad crossing, 20 feet west of railroad, 30 feet south of highway, on right of way; iron post stamped "880"	879.794
Ludlow, 50 feet northeast of Cleveland, Cincinnati, Chicago & St. Louis R. R. station, on south side of Ludlow Creek, in south face of pier of electric railroad overhead bridge, 3.5 feet from west edge; aluminum tablet stamped "893 ADJ 1905"	

Covington southeast 4.5 miles along Troy Pike, thence south to Fenner Pike, thence east to point 3.5 miles west of Troy.

	Feet.
Covington, 4 miles southeast of, on north side of diagonal road at T road west; iron post stamped "958"	958.094
Pleasant Hill, 3 miles east by 0.5 mile south of, at southeast corner of crossroads; iron post stamped "947"	946.588

LIMA QUADRANGLE.

At Wapakoneta.

Wapakoneta, in front of Toledo & Ohio Central Ry. station; top of rail	895.6

CONTINENTAL QUADRANGLE.

At Cloverdale.

Cloverdale, intersection of Toledo, St. Louis & Western R. R. and Cincinnati, Hamilton & Dayton Ry., in front of station; top of rail painted "724"	723.6

APPENDIX.

ELEVATIONS ADJUSTED BY THE COAST AND GEODETIC SURVEY FROM PRECISE LEVELING.

Akron, Alliance, Athens, Blanchester, Batavia, Bowling Green, Columbus Grove, Dayton, Deshler, East Cincinnati, Findlay, Fostoria, Greenfield, Hamilton, Jackson, Lima, Lisbon, McClure, Mason, Massillon, Medina, Miamisburg, Navarre, New London, Norwalk, Ottawa, Parkersburg, Roxabell, Siam, Sidney, Tiffin, Toledo, Troy, Warren, Waynesville, Wellington, West Cincinnati, Wooster, Uhrichsville, and Youngstown Quadrangles.

ALLEN, ASHLAND, ATHENS, AUGLAIZE, BUTLER, CLINTON, CLERMONT, HAMILTON, HENRY, HIGHLAND, HURON, JACKSON, LUCAS, MAHONING, MEDINA, MIAMI, MONTGOMERY, PUTNAM, ROSS, SENECA, SHELBY, STARK, SUMMIT, TRUMBULL, TUSCARAWAS, WARREN, WASHINGTON, WAYNE, AND WOOD COUNTIES.

The following descriptions and elevations are taken from reports of the Coast and Geodetic Survey, and are republished by permission of the superintendent of that bureau. The bench marks were established by the Coast and Geodetic Survey and by the Baltimore & Ohio Railroad Co. from precise levels, and were included in the 1907 adjustment by the Coast and Geodetic Survey. The elevations are likely to be changed only slightly by any future adjustment. For the line from Warwick to Uhrichsville, along the Baltimore & Ohio Railroad, a modified adjustment has been adopted by the United States Geological Survey, as explained on page 17, Bulletin 411. The present accepted elevation of the bench mark at Uhrichsville is 0.25 foot lower than that obtained by the Coast and Geodetic Survey adjustment.

ALLIANCE QUADRANGLE.

Alliance northeast along Pennsylvania R. R. to Snodes.

	Feet.
Alliance, Stark County, about 1.5 miles east of, on Pennsylvania R. R. right of way, east abutment of bridge 66, on the northwest corner; square cut (C. & G. S. b. m. Bridge 66)	1,096.030
Alliance, West Main Street, southeast corner of Knights of Pythias Hall, in south face of base stone, one-third meter above cement walk; red metal disk (C. & G. S. b. m. Q6)	1,102.991
Alliance, northeast corner of Freedom and Main streets, southwest corner of the Lewis Block, about 2 inches from north wall; iron bolt, anchored to foundation and extending slightly above the level of cement walk (C. & G. S. b. m. City)	1,1[illegible]

	Feet.
Alliance, southeast corner of Freedom and Court Streets, in front face of city hall, about one-third meter from south side, on horizontal surface of water table; chiseled square, marked "U. S." (C. & G. S. b. m. R6)	1,119.212
Alliance, north side of Pennsylvania R. R. station, on northwest corner of iron sill of lunch-room door; chiseled square (C. & G. S. b. m. Lunchroom)	1,087.490
Alliance, 1.5 miles east of, on Pennsylvania R. R. right of way, northwest corner of east abutment of bridge 65; chiseled square, marked "U. S." (C. & G. S. b. m. Bridge 65, 1906)	1,055.009
Alliance, 1.7 miles east of, on Pennsylvania R. R. right of way; northeast corner of the east back wall of bridge 64; chiseled square (C. & G. S. b. m. Bridge 64, 1906)	1,062.428
Sebring, Mahoning County, about 0.5 mile west of, on Pennsylvania R. R. right of way, northwest corner of east abutment of open culvert; large square in outline, marked "B.M." (C. & G. S. b. m. West Culvert)	1,109.031
Sebring, 0.5 mile west of, on Pennsylvania R. R. right of way, northwest corner of east abutment of box culvert; chiseled square marked "B. M." (C. & G. S. b. m. East Culvert)	1,106.040
Snodes, 1 mile south of, on Pennsylvania R. R. right of way at milepost 22, in middle of east coping of concrete culvert; chiseled square, marked "U. S." (C. & G. S. b. m. S6)	1,090.454

LISBON QUADRANGLE.

Bench marks near Berlin Center, Mahoning County.

Berlin Center, about 2.5 miles south of, on Pennsylvania R. R. right of way, five telegraph poles north of milepost 20; middle of west end of north concrete abutment of bridge 26 (C. & G. S. b. m. T6)	1,089.090
Berlin Center, about 2 miles south of, 17 telegraph poles south of milepost 24, at southwest corner of Western Reserve line crossing, 15 meters west of track; red metal cap on iron post (C. & G. S. b. m. U6)	1,084.868

WARREN QUADRANGLE.

Berlin Center northeast along Pennsylvania R. R. to point near Miles.

Berlin Center, Mahoning County, 70 meters north of Pennsylvania R. R. station, 15 meters east of tracks, base of the southwest support of railroad water tank; chiseled square (C. & G. S. b. m. V6)	1,106.152
Ellsworth, about 90 meters south of Pennsylvania R. R. station, in northwest corner of large stone step of public school building; chiseled square marked "U.S.B.M." (C. & G. S. b. m. W6)	1,120.666
Rosemont, southeast corner of Pennsylvania R. R. station, on curbing of platform, 5 centimeters from building; chiseled square (C. & G. S. b. m. X6)	1,071.456
Rosemont, 100 meters west of Pennsylvania R. R. station, on public highway, in middle of the north coping of the stone culvert; chiseled square marked "U.S.B.M." (C. & G. S. b. m. Y6)	1,080.878
Rosemont, about 0.3 mile west of station, at public road crossing, in northwest corner of public school grounds; red metal cap on iron post (C. & G. S. b. m. Z6)	1,065.557

	Feet.
North Jackson, about 0.25 mile east of Pennsylvania R. R. station, in southwest corner of east abutment of highway bridge; red metal disk (C. & G. S. b. m. A7)	1,014.652
North Jackson, 45 meters southeast of station at corner of fence, 40 meters east of railroad crossing; red metal cap on iron post (C. & G. S. b. m. B7)	1,024.622
North Jackson, 1.4 miles north of, on Pennsylvania R. R. right of way, one telegraph pole from milepost 7, in middle of east coping of concrete arch bridge 10; chiseled square marked "U.S." (C. & G. S. b. m. C7)	1,001.462
Lordstown, Trumbull County, northwest corner of road crossing, four telegraph poles north of milepost 5, in corner of fence, on land belonging to Ada Horn; red metal cap on iron post (C. & G. S. b. m. D7)	949.010
Lordstown, about 0.8 mile north of, on Pennsylvania R. R. right of way, at milepost 4, on west end of north abutment to bridge 6; chiseled square (C. & G. S. b. m. E7)	919.845
Niles, 2 miles southwest of, near Boenna Crossing, on Baltimore & Ohio R. R. right of way, 328 feet east of Pennsylvania R. R. track, on lower step of the undergrade crossing bridge 423; red metal disk (C. & G. S. b. m. F7)	899.342

YOUNGSTOWN QUADRANGLE.

Point near Niles, Trumbull County, southeast to Struthers, Mahoning County.

Niles, about 1.5 miles southeast of, 2.8 miles east of Boenna Crossing, at southeast corner of road crossing, 49 feet from Baltimore & Ohio R. R. tracks, in corner of fence, on land owned by John Dove; red metal cap on iron post (C. & G. S. b. m. G7)	816.968
Girard, about 0.5 mile west of, on Baltimore & Ohio R. R. right of way, culvert at telegraph pole 81/28½, in middle of south coping; chiseled square marked "U.S.B.M." (C. & G. S. b. m. H7)	817.327
Youngstown, Mahoning County, about 3.5 miles northwest of new Baltimore & Ohio R. R. station, at telegraph pole 79/28½, west end of large cut, on side of hill, 82 feet south of Baltimore & Ohio R. R. tracks, set in clay at an offset in the right-of-way fence; red metal cap on iron post (C. & G. S. b. m. I7)	883.860
Youngstown, 1 mile west of new Baltimore & Ohio R. R. station, on Baltimore & Ohio R. R. right of way, north end of the top step of east abutment of bridge 410; chiseled square marked "U.S.B.M." (C. & G. S. b. m. J7)	865.312
Youngstown, 1 mile west of, at telegraph pole 76/23, on old line east of river, section of rail set vertically in ground beneath the semaphore bridge; top (B. & O. b. m. 381)	842.094
Youngstown, 200 feet east of old Baltimore & Ohio R. R. passenger station, on the old line east of river, in second course of masonry at west end of the retaining wall; copper bolt (B. & O. b. m. 380)	843.707
Youngstown, near Lake Shore & Michigan Southern Ry. station, northwest corner of foundation of west beam supporting the overhead highway bridge, between Baltimore & Ohio R. R. and Pittsburg & Lake Erie R. R. tracks; seat cut (C. & G. S. b. m. Railroad)	847.118
Hazelton, on Baltimore & Ohio R. R. right of way, at Andrews Bros. crossing, top course of north wing wall of east abutment to bridge 24; aluminum tablet stamped "837 ADJ"	

	Feet.
Struthers, 1 mile west of, on Baltimore & Ohio R. R. right of way and south of tracks, on west abutment of bridge 22, in concrete flume; copper bolt (B. & O. b. m. 377)	847.135
Struthers, north end of highway bridge over Pittsburg & Lake Erie R. R. tracks, in southwest corner of the bridge seat; copper bolt (B. & O. b. m. 376)	844.766

AKRON QUADRANGLE.

Akron southwest to Barberton.

Akron, Summit County, 600 feet east of Union Station, in east end of retaining wall on north side of tracks; copper bolt (B. & O. b. m. 441)	1,009.189
Akron, 1 mile southwest of Union Station, in southwest end of northwest coping of culvert along Cleveland, Akron & Columbus Ry. tracks; copper bolt (B. & O. b. m. 442)	993.911
Akron, 3.5 miles southwest of, on Cleveland, Akron & Columbus Ry. bridge over old canal; copper bolt (B. & O. b. m. 443)	976.936
Barberton station; southeast corner of stone doorsill at entrance to ladies' waiting room (B. & O. b. m. 444)	968.109

MASSILLON QUADRANGLE.

Barberton southwest to Clinton, thence northwest to Easton.

Barberton, Summit County, 0.8 mile south of, set in southwest abutment, north side of bridge 18, Cleveland, Akron & Columbus Ry.; copper bolt (B. &. O. b. m. 445)	965.236
Barberton, 2.5 miles west of, 0.6 mile south of milepost H 22, in east end of small culvert; copper bolt (B. & O. b. m. 446)	971.514
Turkeyfoot Junction, near, 300 feet south of milepost H 24, set in west end of small Cleveland, Akron & Columbus Ry. culvert; copper bolt (B. & O. b. m. 447)	968.526
Messenger, about 2 miles east of Warwick; northeast corner of south pier of water tank (Pennsylvania R. R. b. m.)	960.428
Clinton, 0.25 mile northeast of, 0.8 mile southwest of Clinton coaling station, in northwest end of small Cleveland, Akron & Columbus Ry. culvert; copper bolt (B. & O. b. m. 448)	945.687
Warwick, 0.25 mile northeast of, in southeast corner of small Cleveland, Akron & Columbus Ry. culvert; copper bolt (B. & O. b. m. 449)	958.332
Warwick, 0.8 mile northwest of, in northeast corner of old part of Culvert; copper bolt (B. & O. b. m. 450)	958.619
Warwick, about 1.5 miles northwest of, 500 feet west of milepost 59, on east-bound track, in west end of north coping of culvert; copper bolt (B. & O. b. m. 451)	947.379
Easton, Wayne County, 2.8 miles southeast of, 100 feet east of milepost 58, on east-bound track, set in west end of north coping of culvert; copper bolt (B. & O. b. m. 452)	948.009
Easton, 1.8 miles southeast of, opposite milepost 57; section of rail set vertically in ground (B. & O. b. m. 453)	954.326
Easton, 0.7 mile southeast of, opposite milepost 56; section of rail set vertically in ground (B. & O. b. m. 454)	958.992
Easton, 300 feet northwest of station, in north wing of wall of southeast abutment of bridge, on west-bound track; copper bolt (B. & O. b. m. 455)	960.638

	Feet.
Easton, 1.25 miles northwest of, at milepost 54; section of rail set vertically in ground (B. & O. b. m. 456)	955.414

Warwick south along Baltimore & Ohio R. R. to point 2.5 miles south of Massillon.

Warwick, Summit County, 0.5 mile south of, between tracks on mud wall of south abutment of bridge; chiseled point (B. & O. b. m. 1)	952.372
Warwick, 1.8 miles southeast of, at milepost 107; section of rail set vertically in ground (B. & O. b. m. 2)	948.759
Warwick, 2.8 miles southeast of, at milepost 106; section of rail set vertically in ground (B. & O. b. m. 3)	949.890
Canal Fulton, Stark County, 500 feet southeast of station at, between east-bound track and siding at milepost 105; rail section (B. & O. b. m. 4)	947.220
Canal Fulton, 1 mile southeast of, at milepost 104; section of rail set vertically in ground (B. & O. b. m. 5)	948.400
Canal Fulton, 2 miles southeast of, at milepost 103; section of rail set vertically in ground (B. & O. b. m. 6)	944.570
Pauls, about 1 mile northwest of, at milepost 102; section of rail set vertically in ground (B. & O. b. m. 7)	939.088
Crystal Spring, about 1 mile west of, near Pauls, near Coxey's white sand works, on northwest end of retaining wall on northeast side of tracks at milepost 101; chiseled point (B. & O. b. m. 8)	942.460
Crystal Spring, about 0.25 mile west of, at milepost 100; section of rail set vertically in ground (B. & O. b. m. 9)	940.405
Crystal Spring, about 0.8 mile southeast of, at milepost 99; section of rail set vertically in ground (B. & O. b. m. 10)	948.340
Massillon, about 2 miles north of, 250 feet east of milepost 98, in south end of west coping of box culvert on west-bound tracks; square cut (B. & O. b. m. 11)	933.461
Massillon, about 1 mile north of, at milepost 97; section of rail set vertically in ground (B. & O. b. m. 12)	934.109
Massillon, 300 feet east of bridge 4; cut on northeast corner coping Pennsylvania R. R. arch bridge (Pennsylvania R. R. b. m.)	942.276
Massillon, 0.25 mile northwest of, in north end of mud wall of east abutment of bridge at telegraph pole 96/10; copper bolt (B. & O. b. m. 13)	941.359
Massillon, on north end of east back wall of Pennsylvania R. R. bridge 5; cut (Pennsylvania R. R. b. m.)	939.281
Massillon, 0.5 mile southeast of, set in north end of west abutment of highway bridge over river; copper bolt (B. & O. b. m. 14)	935.289
Massillon, about 1.5 miles south of, at telegraph pole 94/4, set in southeast pedestal of water tank at Columbia; copper bolt (B. & O. b. m. 15)	933.357
Massillon, about 2.5 miles south of, set in northeast end of northwest coping of culvert for pipe drain at telegraph pole 93/7; copper bolt (B. & O. b. m. 16)	927.529

WOOSTER QUADRANGLE.

Point near Rittman northwest to point near Creston.

Rittman, Wayne County, 0.5 mile east of, at milepost 53; section of rail set vertically in ground (B. & O. b. m. 457)	957.103
Rittman, 0.5 mile southwest of, at milepost 52; section of rail set vertically in ground (B. & O. b. m. 458)	9

	Feet.
Rittman, 1.5 miles west of, 500 feet west of milepost 51; in northwest abutment in northeast side of bridge 94; copper bolt (B. & O. b. m. 459)	969.213
Rittman, 2.5 miles west of, at milepost 50; section of rail set vertically in ground (B. & O. b. m. 460)	969.904
Sterling, 1 mile east of, in bridge seat at south end of east abutment of Erie R. R. bridge; bronze tablet stamped "964 CANTON"; probably moved in laying double track (B. & O. b. m. 460A)	963.678
Sterling, 0.25 mile east of, north side of tracks opposite milepost 49; vertical rail section (B. & O. b. m. 461)	970.465
Sterling, 0.8 mile northwest of, at milepost 48; section of rail set vertically in ground (B. & O. b. m. 462)	975.020
Sterling, 0.8 mile southeast of, at milepost 47; section of rail set vertically in ground (B. & O. b. m. 463)	982.544
Creston, 0.25 mile northwest of, at milepost 46; section of rail set vertically in ground (B. & O. b. m. 464)	987.325
Creston, 1.25 miles northwest of; at milepost 45; section of rail set vertically in ground (B. & O. b. m. 465)	974.241

MEDINA QUADRANGLE.

Point near Creston northwest to point near Lodi.

Creston, Wayne County, 2.25 miles northwest of, at milepost 44; section of rail set vertically in ground (B. & O. b. m. 466)	961.908
Creston, 3.25 miles northwest of, at milepost 43; section of rail set vertically in ground (B. & O. b. m. 467)	966.755
Lodi, Medina County, 3 miles southeast of, at milepost 42; section of rail set vertically in ground (B. & O. b. m. 468)	970.242
Lodi, 2.5 miles southeast of, set in north end of small culvert at telegraph pole 34/17; copper bolt (B. & O. b. m. 469)	952.182
Lodi, 1 mile southeast of, at milepost 40; section of rail set vertically in ground (B. & O. b. m. 470)	931.890
Lodi, 800 feet east of, in unstable ground; section of rail set vertically in ground (B. & O. b. m. 471)	913.791
Lodi, 1 mile southwest of, at milepost 38; section of rail set vertically in ground (B. & O. b. m. 472)	913.794

WELLINGTON QUADRANGLE.

Point 2 miles southwest of Lodi west to point 1.5 miles west of Sullivan.

Lodi, Medina County, 2 miles southwest of, in northwest end of small culvert at telegraph pole 38/25½; copper bolt (B. & O. b. m. 473)	914.365
Lodi, 3 miles southwest of, on bridge 118, at telegraph pole 39/24½; copper bolt (B. &. O. b. m. 474)	943.523
Lodi, 4 miles west of, in north corner of west abutment on bridge 120, telegraph pole 40/27; copper bolt (B. & O. b. m. 475)	991.217
Homer, 1.8 miles east of, in south end of small culvert at telegraph pole 41/18; copper bolt (B. & O. b. m. 476)	1,011.129
Homer, 0.25 mile east of, at milepost 33; section of rail set vertically in ground (B. & O. b. m. 477)	1,074.159
Newtons, 500 feet west of, at telegraph pole 44/10; section of rail set vertically in ground (B. & O. b. m. 478)	1,095.284

	Feet.
Newtons, 1 mile west of, in south end of small culvert at telegraph pole 45/10; copper bolt (B. & O. b. m. 479)	1,094.515
Newtons, 1.8 miles west of, set in north end of small culvert at milepost 30; copper bolt (B. & O. b. m. 480)	1,101.007
Sullivan, Ashland County, 1.5 miles east of, at milepost 29; section of rail set vertically in ground (B. & O. b. m. 481)	1,119.297
Sullivan, at southwest corner of schoolhouse, in vertical surface of water table; bronze tablet stamped "1136 Canton ADJ 1903"	1,137.443
Sullivan, about 300 feet east of station, on culvert at telegraph pole 48/14, in the west end of north coping; copper bolt (B. & O. b. m. 482)	1,122.261
Sullivan, about 1.5 miles west of, at milepost 26; section of rail set vertically in ground (B. & O. b. m. 483)	1,126.851

NEW LONDON QUADRANGLE.

Nova west along Baltimore & Ohio R. R. to point about 0.8 mile east of Greenwich.

Nova, Ashland County, about 1.5 miles east of, on culvert at telegraph pole 51/14, in the west end of south coping; copper bolt (B. & O. b. m. 484)	1,134.659
Nova, about 0.5 mile east of, north end of small culvert at telegraph pole 52/15; copper bolt (B. & O. b. m. 485)	1,123.337
Nova, about 325 feet east of station on a small culvert, at top of beveled surface; northeast corner of north coping (B. & O. b. m. 485A)	1,111.050
Nova, T. 1 N., R. 19 W., in foundation wall of the United Brethren Church, on south face of southeast corner; aluminum tablet stamped "1127 ADJ 1903"	1,127.315
Nova, about 0.6 mile west of, culvert at telegraph pole 53/17½, in west end of north coping; copper bolt (B. & O. b. m. 486)	1,103.946
Nova, about 2 miles northwest of, large arch bridge at telegraph pole 55/1½, in east end of north coping; copper bolt (B. & O. b. m. 487)	1,071.539
Hereford, about 1.9 miles east of, small culvert at telegraph pole 56/6, in west end of south coping; copper bolt (B. & O. b. m. 488)	1,050.135
Hereford, about 0.9 mile east of, bridge at telegraph pole 57/5, in south end of east abutment; copper bolt (B. & O. b. m. 489)	1,037.597
Hereford, near, on north side of east abutment of a steel girder bridge, about 800 feet west of station; copper bolt (B. & O. b. m. 490)	1,014.894
Hereford, about 1.5 miles west of, on large arch bridge, in east end of north coping; copper bolt (B. & O. b. m. 491)	988.458
Ramey, about 0.25 mile west of, on large arch bridge at telegraph pole 60/18, in east end of north coping; copper bolt (B. & O. b. m. 492)	1,000.707
Greenwich, Huron County, about 2.8 miles east of, on arch culvert at telegraph pole 61/21½, in east end of north coping; copper bolt (B. & O. b. m. 493)	1,028.983
Greenwich, about 1.8 miles east of, on arch culvert at telegraph pole 62/21½, in west end of north coping; copper bolt (B. & O. b. m. 494)	1,042.458
Greenwich, about 0.8 mile east of, on arch culvert at telegraph pole 62/23½, in east end of north coping; copper bolt (B. & O. b. m. 495)	1,038.95

NORWALK QUADRANGLE.

Point 1 mile west of Greenwich west to point 1 mile east of Chicago Junction (bench marks established by Baltimore & Ohio R. R. adjusted by Coast and Geodetic Survey).

	Feet.
Greenwich, Huron County, 0.25 mile west of, in south end of east abutment of bridge for undergrade street crossing; copper bolt (B. & O. b. m. 496)	1,029.623
Greenwich, 1 mile west of, in east end of north coping of large arch at telegraph pole 65/17½; copper bolt (B. & O. b. m. 497)	1,009.423
Greenwich, 1.6 miles west of, 20 feet north of tracks, by telegraph pole 65/5; vertical rail section (B. & O. b. m. 498)	1,017.477
Greenwich, 2.8 miles west of, in east end of north coping of small culvert at telegraph pole 67/7½; copper bolt (B. & O. b. m. 499)	1,035.688
Boughtonville, 1.5 miles east of, in east pedestal of highway bridge at telegraph pole 69/10, south of tracks; copper bolt (B. & O. b. m. 500)	1,020.131
Boughtonville, 300 feet east of, in west end of south coping of arch bridge; copper bolt (B. & O. b. m. 501)	988.324
Boughtonville, 0.8 mile west of, in east end of south coping of culvert at telegraph pole 70/18; copper bolt (B. & O. b. m. 502)	964.390
Boughtonville, about 1.8 miles west of, at telegraph pole 71/18, in south end of east abutment of an undergrade crossing bridge; copper bolt (B. & O. b. m. 503)	953.727
Chicago Junction, about 3 miles east of, 700 feet east of milepost 3; originally a copper bolt set in the south end of east abutment of an undergrade crossing bridge. In 1905 it was found that the copper bolt had been removed and the top surface of the stone close to the hole on the south side was used as the bench mark (B. & O. b. m. 504)	935.483
Chicago Junction, 2 miles east of, opposite milepost 2; section of rail set vertically in ground (B. & O. b. m. 505)	937.905
Chicago Junction, about 1 mile east of, 500 feet west of milepost 1, set in the east end of south coping of a culvert; copper bolt (B. & O. b. m. 506)	928.175

SIAM QUADRANGLE.

Chicago Junction west along Baltimore & Ohio R. R. to point 1 mile west of Scipio siding.

Chicago Junction, Huron County, 600 feet east of Baltimore & Ohio R. R. crossing; section of rail set vertically in ground (B. & O. b. m. 507)	914.793
Chicago Junction, corner of Washington and First streets; cross cut in top surface of east end of top step of St. Francis Xavier Church (C. & G. S. b. m. F5)	918.142
Chicago Junction, corner of Myrtle Avenue and Pearl Street, at southwest corner of the Shiedley Hotel block, on the side facing Myrtle Avenue, in second course of brick above water table; copper bolt (C. & G. S. b. m. G5)	929.666
Chicago Junction, about 656 feet south of Baltimore & Ohio R. R. tracks, on west side of Myrtle Avenue, in east end of sandstone sill of the Home Savings & Banking Co.'s building; red metal disk (C. & G. S. b. m. H5)	925.867

	Feet.
Chicago Junction, about 2.5 miles west of, on Baltimore & Ohio R. R. right of way, at second telegraph pole west of milepost 269 (c), on a knoll 39 feet south of the track; red metal cap on iron post (C. & G. S. b. m. I5)	912.595
Chicago Junction, about 3 miles west of, on Baltimore & Ohio R. R. right of way, 3.5 telegraph poles east of milepost 268, and 16 feet north of track, in top surface of coping of a culvert; chiseled square marked "U.S.B.M." (C. & G. S. b. m. J5)	910.939
Chicago Junction, about 5 miles west of, on Baltimore & Ohio R. R. right of way, 8 telegraph poles east of milepost 266, in center of top surface of the gray sandstone coping of a culvert; copper bolt (C. & G. S. b. m. K5)	922.188
Siam, Seneca County, on Baltimore & Ohio R. R. right of way, 246 feet west of Pennsylvania R. R. crossing, about 6 feet south of track, in center of a concrete block, about 3 by 4 feet on the top surface, set level with the grade; red metal disk (C. & G. S. b. m. L5)	953.179
Siam, on Baltimore & Ohio R. R. right of way, 1,230 feet west of Pennsylvania R. R. crossing, about 48 feet north of track, in corner of fence at a road crossing; red metal cap on iron post (C. & G. S. b. m. M5)	955.386
Siam, about 3 miles west of, on Baltimore & Ohio R. R. right of way, in the north end of west abutment of an undergrade crossing bridge; chiseled square marked "U.S.B.M." (C. & G. S. b. m. N5)	954.714
Scipio siding, about 1 mile west of, on Baltimore & Ohio R. R. right of way, 3 telegraph poles east of signboard "1 mile to Scipio," in center of the top surface of the north end of a concrete culvert; copper bolt (C. & G. S. b. m. O5)	928.730

TIFFIN QUADRANGLE.

Republic west along Baltimore & Ohio R. R. to point 2.5 miles west of Tiffin.

Republic, Seneca County, about 0.25 mile east of, on Baltimore & Ohio R. R. undergrade crossing bridge, over Marion State road, on the top surface of southernmost stone in the lower course; square cut in outline, marked "859 REPUBLIC"	860.353
Republic, in southwest corner of town hall, on west side, in vertical face of water table; aluminum tablet stamped "883 COL."	884.146
Republic, near, 12 telegraph poles west of milepost 255, on a knoll in Baltimore & Ohio R. R. right of way, 39 feet south of track; chiseled square on top of post lettered "U.S.B.M." (C. & G. S. b. m.)	872.279
Seneca, 0.5 mile west of signboard, on Baltimore & Ohio R. R. right of way, 547 feet south of track, at offset in right-of-way fence; red metal cap on iron post (C. & G. S. b. m. Q5)	822.517
Tiffin, about 3 miles east of, on Baltimore & Ohio R. R. right of way, in center of south coping of stone arch bridge 58; copper bolt (C. & G. S. b. m. R5)	790.612
Tiffin, about 1 mile east of, on Baltimore & Ohio R. R. right of way, 0.25 mile west of milepost 248 and 984 feet east of junction of Baltimore & Ohio and Pennsylvania R. Rs., in center of south girder (concrete) of bridge 61; red metal disk (C. & G. S. b. m. S5)	762.468
Tiffin, at southwest corner of courthouse, west face, in window sill; tablet stamped "757 COL."	758.242

	Feet.
Tiffin, on Munroe Street Bridge over Sandusky River, in east side of north abutment, about 2 feet from guard rail, on the second course of stone; copper bolt (C. & G. S. b. m. T5)	741.801
Tiffin, corner of Washington and Welmore Streets, at front entrance to Catholic church, cut in the east end of lower step; chiseled square marked "775 TIFFIN"	775.296
Tiffin, about 2.5 miles west of, on Baltimore & Ohio R. R. right of way, 1,312 feet west of milepost 245, in the north end of west abutment of a bridge over a creek; red metal disk (C. & G. S. b. m. U5)	761.193
Fostoria, 2.5 miles west of, at crossing, 164 feet north of Baltimore & Ohio R. R. tracks, in west end of south abutment of a small highway bridge over creek; copper bolt (C. & G. S. b. m. C6)	773.584
Godsend, Hancock County, near, on Baltimore & Ohio R. R. right of way, 492 feet west of water tank, north end of west abutment of steel girder bridge over a small creek; copper bolt (C. & G. S. b. m. D6)	754.453

FOSTORIA QUADRANGLE.

Bascom northwest along Baltimore & Ohio R. R. to point 2.5 miles west of Fostoria.

Bascom, Seneca County, about 2 miles east of, on Baltimore & Ohio R. R. right of way, 492 feet west of milepost 243, north end of west abutment of bridge 68 over Wolf Creek; chiseled square marked "U.S.B.M." (C. & G. S. b. m. V5)	764.762
Bascom, about 1 mile east of, 296 feet west of milepost 242 and 82 feet south of Baltimore & Ohio R. R. tracks, on the farm of Joseph Leonard, disk at northeast corner of junction of roads; red metal cap on iron post (C. & G. S. b. m. W5)	778.241
Bascom, near Crumm's store, at northwest corner of crossroads, in bottom of round hole in stone used for crossing; cross marked "776 BASCOM"	776.527
Bascom, 0.2 mile south of, south of cemetery, in southwest abutment of an iron highway bridge over creek; aluminum tablet stamped "766 TOL."	767.305
Bascom, about 2 miles west of, on Baltimore & Ohio R. R. right of way, road crossing, at milepost 239, 16.4 feet north of track, on top step of east side of a sandstone culvert; red metal disk (C. & G. S. b. m. X5)	768.370
Fostoria, about 3 miles east of, on Baltimore & Ohio R. R. right of way, in north end of west abutment of a steel girder bridge over Raccoon Creek; chiseled square marked "U.S.B.M." (C. & G. S. b. m. Y5)	767.703
Fostoria, about 2 miles east of, on Baltimore & Ohio R. R. right of way, on north side of track; copper bolt in center of the capstone of a culvert (C. & G. S. b. m. Z5)	768.261
Fostoria, northwest corner of Jones and Main streets; top surface of check valve of the city water plug, marked "778 FOSTORIA"	779.853
Fostoria, corner of Main and Center Streets, in southwest corner of First National Bank Building, east side of Center Street entrance, in vertical surface of the water table; red metal disk (C. & G. S. b. m. A6)	781.072
Fostoria, at southeast corner of Tiffin and Union streets, 1 meter from curb, in top of stone post; chiseled square marked "U.S.B.M." (C. & G. S. b. m. B6)	782.877

FINDLAY QUADRANGLE.

Bloomdale northwest along Baltimore & Ohio R. R. to point 0.5 mile west of North Baltimore.

	Feet.
T. 3 N., R. 12 E., sec. 31, 1.5 miles east of Bloomdale, in south end of east abutment of an iron highway bridge; aluminum tablet stamped "740 TOLEDO"	740.625
Bloomdale, Wood County, 0.8 mile east of, at city limits, at northeast corner of road junction close to a rail fence; chiseled square on top of stone post lettered "U.S.B.M." (C. & G. S. b. m. E6)	742.974
Bloomdale, southwest corner of Main Street and Second Street north of Baltimore & Ohio R. R. tracks, in brick building used as hardware store, in the north end of stone sill; square cut in outline marked "749 BLOOMDALE"	749.771
Bloomdale, at corner of Garfield and Mulberry streets, main entrance of Trinity Methodist Episcopal Church, in top face of second step; red metal disk (C. & G. S. b. m. F6)	752.238
Bairdstown, on Randolph Avenue, 328 feet south of Baltimore & Ohio R. R. station, in the south doorstep of a double house belonging to E. Knodle; square cut (C. & G. S. b. m. H6)	739.553
Galatea, on Baltimore & Ohio R. R. right of way, 492 feet east of Toledo & Ohio Central Ry. crossing, on upper step of the northwest abutment of a large culvert; chiseled square marked "U.S.B.M." (C. & G. S. b. m. I6)	727.458
North Baltimore, west side of Main Street, 131 feet north of Baltimore & Ohio R. R. tracks, in north end of the sill of the south part of double store marked "A. J. Steele, 1900"; red metal disk (C. & G. S. b. m. J6)	734.018
North Baltimore, 0.5 mile south of, in southwest abutment of iron bridge over a creek; bronze tablet stamped "726 TOLEDO"	726.640
North Baltimore, 0.5 mile west of, at northeast corner of intersection of Broadway and street at city limits; red metal cap on iron post (C. & G. S. b. m. K6)	727.559

DESHLER QUADRANGLE.

North Baltimore west along Baltimore & Ohio R. R. to point 1 mile east of Deshler.

North Baltimore, Wood County, about 1.5 miles west of, at road crossing, in south end of a culvert, in center of the top; copper bolt marked "U.S.B.M." (C. & G. S. b. m. L6)	717.320
North Baltimore, about 2.5 miles west of, on Baltimore & Ohio R. R. right of way, at road crossing, in south end of concrete culvert; chiseled square marked "U.S.B.M." (C. & G. S. b. m. M6)	715.051
Hoytville, about 1 mile east of, at road crossing 164 feet south of Baltimore & Ohio R. R. tracks, 33 feet south of the junction of highway, on west end of north abutment of a small iron bridge; red metal disk (C. & G. S. b. m. N6)	707.577
Hoytville, about 1 mile west of, at road crossing, 33 feet south of Baltimore & Ohio R. R. tracks, on west end of small highway culvert, in middle stone, 3.2 inches from the west face; copper bolt (C. & G. S. b. m. O6)	709.289
Deshler, Henry County, about 1 mile east of, on Baltimore & Ohio R. R. right of way, at a road crossing, in north end of concrete culvert; red metal disk in center of top surface (C. & G. S. b. m. P6)	711.569

Deshler southwest along Cincinnati, Hamilton & Dayton Ry. to Leipsic.

	Feet.
Deshler, Henry County, northeast corner of Maple and Keiser streets, in southeast corner of main building Presbyterian church, in water table, east face, about 1 foot north of south corner and 3 feet above ground; brass bolt marked with a horizontal line (C. & G. S. b. m. H1)	713. 716
Deshler, north side of Main Street, about 175 feet east of Cincinnati, Hamilton & Dayton Ry. track, on bank building owned by A. W. Lee, on west end of base stone, under window west of entrance; chiseled square (C. & G. S. b. m. I1)	713. 140
Belmore, Putnam County, northeast corner of Defiance and Walnut streets, in east face of the foundation of the Starling Building, 18 feet north of south corner of building, 8 inches below bottom of baseboard, and 10 inches above ground, intersection of two approximately horizontal and vertical chisel cuts in brass bolt leaded horizontally and lettered "U. S. C. & G. S." (C. & G. S. b. m. J1)	736. 700
Leipsic, north side of Railroad Street, about 126 feet east of Main Street, top of foundation, northeast corner of the Lampe Building, under the east end of the window, 11 inches west of corner buttress, 1 foot above sidewalk; chiseled square (C. & G. S. b. m. K1)	765. 964
Leipsic, on south side of Commercial Street, 129 feet east from east side of Main Street, on foundation at northeast corner of the Heffler House, 6 inches west of east face and 35 inches above the flagging of sidewalk; brass bolt marked with a horizontal line (C. & G. S. b. m. L1)	763. 703

NAVARRE QUADRANGLE.

Point 4.25 miles south of Massillon south to point 2 miles northwest of Canal Dover.

Massillon, Stark County, about 4.25 miles south of, in north end of west coping of large concrete arch culvert near where old line is crossed by present line; copper bolt (B. & O. b. m. 17)	940. 066
Navarre, about 0.8 mile northeast of, in southwest end of southeast coping of large stone arch 450 feet southwest of first Wheeling & Lake Erie R. R. crossing; copper bolt (B. & O. b. m. 18)	980. 909
Navarre, 0.8 mile southwest of Navarre, at milepost 89; section of rail set vertically in ground (B. & O. b. m. 19)	1, 003. 488
Justus, 0.5 mile north of, 300 feet south of Wheeling & Lake Erie R. R. crossing, in north end of west coping of small culvert at telegraph pole 88/5; copper bolt (B. & O. b. m. 20)	1, 000. 364
Justus, 0.5 mile south of, in west end of south abutment of arch culvert near milepost 87; copper bolt (B. & O. b. m. 21)	976. 711
Justus, 1.5 miles south of, in west end of south abutment of arch culvert at telegraph pole 86; copper bolt (B. & O. b. m. 22)	974. 910
Beach City, 1 mile north of, in south end of west coping of stone culvert for traction line near railroad; copper bolt (B. & O. b. m. 23)	976. 079
Beach City, 800 feet north of station, in west end of south abutment of bridge over creek; copper bolt (B. & O. b. m. 24)	969. 456
Beach City, 0.8 mile southeast of, in southwest end of southeast abutment of bridge; copper bolt (B. & O. b. m. 25)	961. 937
Beach City, 2 miles southeast of, in southwest end of back wall, northwest abutment of bridge; copper bolt (B. & O. b. m. 26)	944. 603

	Feet.
Strasburg, Tuscarawas County, 2 miles northwest of, at milepost 81; section of rail set vertically in ground (B. & O. b. m. 27)	929.665
Strasburg, 1 mile northwest of, at milepost 80; section of rail set vertically in ground (B. & O. b. m. 28)	924.741
Strasburg, at milepost 79; section of rail set vertically in ground (B. & O. b. m. 29)	914.099
Strasburg, about 0.8 miles southeast of, in southwest end of back wall of southeast abutment of bridge; copper bolt (B. & O. b. m. 30)	912.671
Strasburg, about 1 mile southeast of, near milepost 78, in first course of masonry, southeast end of southwest abutment of trolley overhead bridge; copper bolt (B. & O. b. m. 31)	909.698
Strasburg, about 2 miles southeast of, 500 feet northwest of milepost 77, in southeast end of southwest coping of culvert; copper bolt (B. & O. b. m. 32)	901.593
Strasburg, 3 miles southeast of, in south end of west coping of culvert, telegraph pole 76/6; copper bolt (B. & O. b. m. 33)	897.046
Canal Dover, 2 miles northwest of, at milepost 75; section of rail set vertically in ground (B. & O. b. m. 34)	886.023

CANAL DOVER QUADRANGLE.

Bench marks established by Baltimore & Ohio R. R. near Canal Dover.

Canal Dover, Tuscarawas County, 1 mile northwest of, set in southwest end of bridge seat of southeast abutment of culvert at telegraph pole 74/4; copper bolt (B. & O. b. m. 35)	881.756
Canal Dover, 0.25 mile west of station, in east pedestal of water tank, at telegraph pole 73/11; copper bolt (B. & O. b. m. 36)	874.694
Canal Dover, 0.5 mile southeast of, in northeast end of mud wall of northwest abutment of Tuscarawas River Bridge; copper bolt (B. & O. b. m. no. 37)	884.847
Canal Dover, 1.25 miles southeast of, at telegraph pole 72/1; section of rail set vertically in ground (B. & O. b. m. 38)	892.905
Canal Dover, about 1.25 miles southeast of, 200 feet southeast of telegraph pole 72/1; section of rail set vertically in ground (B. & O. b. m. 38A)	893.008

UHRICHSVILLE QUADRANGLE.

New Philadelphia southeast to point 1 mile north of Uhrichsville.

New Philadelphia, Tuscarawas County, 1 mile northwest of, at milepost 71; section of rail set vertically in ground (B. & O. b. m. 39)	888.193
New Philadelphia, at milepost 70; section of rail set vertically in ground (B. & O. b. m. 40)	878.525
New Philadelphia, about 0.5 mile southeast of, in northwest end of southwest coping of culvert; copper bolt (B. & O. b. m. 41)	866.580
New Philadelphia, about 2 miles southeast of, on northeast side of tracks at milepost 68; rail section (B. & O. b. m. 42)	859.046
New Philadelphia, about 3 miles southeast of, in southwest end of southeast abutment of bridge at telegraph pole 67/1; copper bolt (B. & O. b. m. 43)	855.963
Goshen, about 0.8 mile northwest of, in center of mud wall of southeast abutment of bridge at telegraph pole 66/18, northeast of present tracks; copper bolt (B. & O. b. m. 44)	855.682
Goshen, 0.5 mile southeast of, northeast side of tracks at telegraph pole 65/15; rail section (B. & O. b. m. 45)	850.456

	Feet.
Midvale, quarter mile west of, in south end of east abutment of bridge at telegraph pole 64/15; copper bolt (B. & O. b. m. 46)	849.848
Midvale, 0.5 mile southeast of, southwest of track in mud wall of southeast abutment of bridge at telegraph pole 63/20; copper bolt (B. & O. b. m. 47)	853.141
Uhrichsville, about 1 mile north of, in west end of mud wall of south abutment of undergrade highway crossing bridge near milepost 62; copper bolt (B. & O. b. m. 48)	862.029

PARKERSBURG QUADRANGLE.

Belpre west along Baltimore & Ohio Southwestern R. R. to Little Hocking.

Belpre, on wing wall of second pier from west end of Baltimore & Ohio Southwestern R. R. bridge across Ohio River; chiseled square marked B M (C. & G. S. b. m. XL)	621.030
Little Hocking, southwest corner of abutment of railroad bridge over Little Hocking Creek, near its junction with Ohio River; chiseled square marked B M (C. & G. S. b. m. XLI)	623.398

KENO QUADRANGLE.

Bench mark 0.5 mile east of Coolville.

Coolville, about 0.5 mile east of, on coping of abutment of a railroad bridge; chiseled square marked B M (C. & G. S. b. m. XLII)	633.272

CHESTER HILL QUADRANGLE.

Coolville west along Baltimore & Ohio Southwestern R. R. to Canaanville.

Coolville, Athens County, about 3.8 miles west of, on east abutment of small railroad bridge; chiseled square marked B M (C. & G. S. b. m. XLIII)	606.153
Guysville, about 1 mile west of, on east abutment of Baltimore & Ohio R. R. bridge; chiseled square marked B M (C. & G. S. b. m. XLIV)	617.345
Guysville, about 2.5 miles west of, on west abutment of railroad bridge over Little Hocking River; chiseled square marked "B M" (C. & G. S. b. m. XLV)	621.889
Canaanville, about 492 feet east of Canaan Chapel, on west abutment of small bridge; chiseled square marked "B M" (C. & G. S. b. m. XLVI)	623.767

ATHENS QUADRANGLE.

Stewart west along Baltimore & Ohio Southwestern R. R. to Athens.

Stewart, Athens County, about 0.8 mile west of, on west abutment of railroad bridge over Little Hocking River; chiseled square marked "B M" (C. & G. S. b. m. XLVII)	616.420
Stewart, 1.2 miles east of, on top of wall of west abutment of railroad bridge; chiseled square marked "B M" (C. & G. S. b. m. XLVIII)	615.347
Canaanville, about 1.5 miles west of, on coping of a railroad culvert; chiseled square marked "B M" (C. & G. S. b. m. XLIX)	630.325

	Feet.
Athens, on south abutment (east side, fourth step from top) of road bridge over railroad and Hocking River; chiseled square marked "B M" (C. & G. S. b. m. L)	649.169
Athens, on top of pier of the railroad bridge over the Hocking River; chiseled square marked "B M" (C. & G. S. b. m. P)	656.105

ZALESKI QUADRANGLE.

Athens west along Baltimore & Ohio Southwestern R. R. to Zaleski.

Moonville, on east abutment of railroad bridge over Raccoon Creek; chiseled square marked "B M" (C. & G. S. b. m. LI)	712.160
Zaleski, 1 mile south of, on south abutment of railroad bridge over Raccoon Creek; chiseled square marked "B M" (C. & G. S. b. m. LII)	714.304

JACKSON QUADRANGLE.

Hamden west along Baltimore & Ohio Southwestern R. R. to Londonderry.

Hamden, about 0.5 mile east of, on coping of a small drain or culvert; chiseled square marked "B M" (C. & G. S. b. m. LIII)	705.481
Londonderry, about 1.5 miles east of, on east abutment of railroad bridge over Big Salt Creek; chiseled square marked "B M" (C. & G. S. b. m. LIV)	600.638

CHILLICOTHE QUADRANGLE.

Schooleys Station west along Baltimore & Ohio Southwestern R. R. to Chillicothe.

Schooleys, 1.5 miles east of, on east abutment of railroad bridge over Walnut Creek; chiseled square marked "B M" (C. & G. S. b. m. LV)	657.572
Chillicothe, on pedestal of lamp-post on the north side of steps of front entrance of the courthouse; chiseled square marked "B M" (C. & G. S. b. m. Q)	638.001

ROXABELL QUADRANGLE.

Chillicothe west along Baltimore & Ohio Southwestern R. R. to Musselman.

Musselman, Ross County, about 1.25 miles east of, on west abutment of railroad bridge over branch of Paint Creek; chiseled square marked "B M" (C. & G. S. b. m. LVI)	699.646
Musselman, about 0.25 mile west of, on east abutment of railroad bridge over branch of Paint Creek; chiseled square marked "B M" (C. & G. S. b. m. LVII)	712.186

GREENFIELD QUADRANGLE.

Bench mark 1 mile east of Lyndon.

Lyndon, about 1 mile east of, on east abutment of railroad bridge; chiseled square marked "B M" (C. & G. S. b. m. LVIII)	911.671

BLANCHESTER QUADRANGLE.

Martinsville west along Baltimore & Ohio Southwestern R. R. to Clinton Valley.

	Feet.
Martinsville, on east abutment of railroad bridge; chiseled square marked "B M" (C. & G. S. b. m. LIX)	1,056.609
Clinton Valley station, about 0.3 mile east of, on east abutment of railroad bridge; chiseled square marked "B M" (C. & G. S. b. m. LX)	990.047

BATAVIA QUADRANGLE.

Bench mark established 3.25 miles east of Loveland.

Loveland, about 3.25 miles east of, on west abutment of railroad bridge; chiseled square marked "B M" (C. & G. S. b. m. LXI)	692.924

EAST CINCINNATI QUADRANGLE.

Loveland southwest along Baltimore & Ohio Southwestern R. R. to Cincinnati.

Loveland, on east abutment of railroad bridge over Little Miami River; chiseled square marked "B M" (C. &. G. S. b. m. R)	581.882
Remington, short distance west of, on pier of railroad bridge over Sycamore Creek; chiseled square marked "B M," reported destroyed in 1899 (C. & G. S. b. m. LXII)	590.861
Cincinnati, courthouse at, on south face of pillar at south side of main entrance on Main Street, 3 inches above flagging; copper bolt projecting 1.5 inches from masonry on west side; flat surface which surrounds the bench mark is inscribed, "B M No. 1 115′ 25." (C. & G. S. b. m. T, or City b. m. No. 1)	546.537

Glendale south to St. Bernard.

Cincinnati, 12.3 miles north of, Cincinnati, Hamilton & Dayton Ry. bridge 8 over Mill Creek, south abutment, east end, first step below bridge seat course, 6 inches west of east face, 12 inches south of north face; chiseled square (C. & G. S. b. m. J4)	573.305
Lockland, Hamilton County, Collectors Lock, 10 feet north of north side of Lock Street on east wall of lock, on coping stone, 5.6 feet north of south gate, 4 inches east of west face of wall; chiseled square (C. & G. S. b. m. T4)	574.085
Renssalaer, about 1 mile north of Carthage, on Cincinnati, Hamilton & Dayton Ry., at intersection of Hamilton pike and Forest Avenue, on north abutment of viaduct, west end, first step below bridge seat course, on southwest quarter of stone, 6 inches from face and 8 inches from end of stone, 18.5 feet north of outside rail; chiseled square (C. & G. S. b. m. K4)	538.987
Carthage, southeast corner of Jackson and Fourth streets, west side of Christian Church building (1879), on water table at base of tower, 6 inches north of south angle of tower and 1.8 feet above ground; brass bolt marked with a horizontal line (C. & G. S. b. m. L4)	551.403

	Feet.
Carthage, 10 miles north of Cincinnati on line of Miami & Erie Canal, on south abutment of Fourth Street Bridge over canal, west end, 6.5 feet above towpath and 2.5 feet below floor of bridge on second step above retaining wall, on seventh step below coping, 2 inches from end and 6 inches from face of stone; chiseled square (C. & G. S. b. m. S4)	551.264
St. Bernard, about 8 miles north of Cincinnati, on Miami & Erie Canal and Baltimore & Ohio Southwestern R. R., on east face of west abutment of railroad bridge over canal, 4 feet above towpath, in eighth course of masonry from top, 5.75 feet north of prominent corner in southwest bridge-seat stone; horizontal groove in bottom of square cut three-eighths inch deep and 1 inch square, lettered "U. S. C. & G. S." (C. & G. S. b. m. R4)	548.352

TOLEDO QUADRANGLE.

Alexis southwest along highways and Cincinnati, Hamilton & Dayton Ry. to Roachton.

Alexis, Lucas County, at intersection of Lake Shore & Michigan Southern Ry. and Ann Arbor R. R., west of Lake Shore & Michigan Southern Ry. track, northeast of Ann Arbor R. R. track, on west abutment, south side, of long culvert of very large stone, first step below coping at northwest corner, 5 inches from either face; chiseled square, marked "B M" (C. & G. S. b. m. U)	585.481
Toledo, northern part of city near Maumee River, west side of Summit Avenue and north corner of Columbus Avenue, on frame building; copper nail on east side of sign (C. & G. S. b. m. Toledo City No. 165)	596.419
Toledo, north bank of Maumee River, 348 feet above River Place, 4.38 feet south of south edge of flagging in River Park; stone triangulation monument set in ground. The point taken is the east point of the triangle cut in stone (C. & G. S. b. m. Park △)	601.119
Toledo, north bank of the Maumee River, on north abutment of the Pennsylvania R. R. bridge, east side, on retaining wall, 15 inches west of the northwest corner of bridge-seat block and 3 feet above it; chiseled square, marked "B M" (C. & G. S. b. m. V)	589.117
Toledo, northeast corner of Water and Madison streets, on southwest corner of traction company's power house, on top of sandstone water table just where brick begins, about 3 feet above sidewalk; marked by a chiseled square (C. & G. S. b. m. power house)	582.703
Toledo, on United States custom office building, southeast corner of Madison and St. Clair Streets, 15 feet south of south side of entrance on St. Clair Street, on south face of pilaster angle, 6 inches east of west face and 4.9 feet above ground; brass bolt marked with horizontal line (C. & G. S. b. m. W)	603.888
Toledo, northwest corner of customhouse building, cross cut on top of granite water table just where sandstone begins; outer quarter of cross (C. & G. S. b. m. post office)	602.560
Toledo, southwest corner of Madison and Summit streets, on northeast corner of water table of Roberts's drug store; cross (C. & G. S. b. m. Toledo City No. 44)	596.370
Toledo, on east abutment of Pennsylvania Railroad bridge over Maumee River, north of track, on coping stone, 9 inches north of north side of guard timber of track; highest point at northerly part of a cross (C. & G. S. b. m. Toledo City No. 296)	590.352

	Feet.
Perrysburg, about 3 miles north of, on road to Toledo (on which electric railroad runs), 480 feet north of August Broke's house, in west face of culvert under road, 26 inches north of north spring of arch and 28 inches above top of arch (underside); brass bolt marked with a horizontal line (C. & G. S. b. m. X)	603.129
Perrysburg, 1,043 feet south of station, on west end of culvert, under Cincinnati, Hamilton & Dayton Ry. track, 32 inches north of spring line and 18 inches above it; brass bolt, 26 inches above ground, marked with a horizontal line (C. & G. S. b. m. Y)	615.696
Roachton, Wood County, just north of north line of Middleburg Township, about 300 feet west of Cincinnati, Hamilton & Dayton Ry. track, in foundation of residence of W. C. Parrin, center of east side, in east face of bay window, 2.2 feet south of north angle and 1.8 feet above ground, in second brick below wooden water table; horizontal line in brass bolt leaded horizontally (C. & G. S. b. m. Z)	647.595

BOWLING GREEN QUADRANGLE.

Hull Prairie southwest along Cincinnati, Hamilton & Dayton Ry. to Tontogany.

Hull Prairie, Wood County, on Cincinnati, Hamilton & Dayton Ry., about 200 feet south of station, in southeast quarter of stone culvert on first step below bridge seat, 5 inches east of east end of bridge seat course; chiseled square 4.5 inches south of north face (C. & G. S. b. m. A1)	660.514
Haskins, 820 feet west of Cincinnati, Hamilton & Dayton Ry. track on Sugar Street, south face of public school building, in water table 4 feet 10 inches above ground, 1 foot 9 inches east of east side of entrance; brass bolt marked with a horizontal line (C. & G. S. b. m. B1)	667.702
Tontogany, southeast corner of Main and Broad streets, at west side of entrance to Waltz store, "1894" in northwest corner of iron plate under column; top of a surface seven-eighths inch square marked by a cut of a cold chisel (C. & G. S. b. m. C1)	669.510

McCLURE QUADRANGLE.

Tontogany southwest along Cincinnati, Hamilton & Dayton Ry. to Custar.

Weston, Wood County, very near south center of sec. 35, about 150 feet east of Cincinnati, Hamilton & Dayton Ry. track, on south side of Main Street, at east side of east entrance on northeast corner of iron pedestal; top of surface marked by a square cut with a cold chisel (C. & G. S b. m. D1)	683.611
Weston, in foundation of First Methodist Church, erected in 1895, in north face of foundation, 3 feet 10 inches west of west face of belfry tower, in second course of masonry below the water-table course, 2 feet above ground; brass bolt marked with horizontal line (C. & G. S. b. m. E1)	682.705
Weston, about 100 feet east of Cincinnati, Hamilton & Dayton Ry. track, north side of Main Street, northwest corner of the Citizens' Bank building; top of corner stone just below brick (C. & G. S. b. m. Weston Village)	682.029
Milton Center, east side of Railroad Street, at south side of east and west alley, in stone building of John Biverstock, on north end of base stone below window; chiseled square (C. & G. S. b. m. F1)	689.824

Custar, northwest corner of Superior and Linn Streets, in northeast corner of foundation of public school building, 1 foot 10 inches west of east face and 3 feet 8 inches above ground; brass bolt marked with a horizontal line (C. & G. S. b. m. G1) .... Feet. 696.637

OTTAWA QUADRANGLE.

Leipsic southwest along Cincinnati, Hamilton & Dayton Ry. to Ottawa.

Ottawa Township, Putnam County, on line of Cincinnati, Hamilton & Dayton Ry., about 0.5 mile below G. W. Miller's residence and 492 feet north of milepost 50 T, on southeast quarter of stone culvert 54, on bridge seat course, 6 inches north of east end of stone above, and 2 feet 10 inches east of wing angle; chiseled square (C. & G. S. b. m. M1) 743.696

Ottawa, south side of Mainleron Street, about 170 feet west of railroad, on large stone step of foundation, 5 feet east of east side of east pillar of stairway entrance; chiseled square (C. & G. S. b. m. N1) 729.338

COLUMBUS GROVE QUADRANGLE.

Ottawa south along Cincinnati, Hamilton & Dayton Ry. to Lima.

Columbus Grove, about 3 miles north of, 110 feet above milepost 56, on the southwest quarter of abutment of Cincinnati, Hamilton & Dayton Ry. bridge 51, on second step below bridge seat course, about 6 inches from face and 6 inches from edge of stone; chiseled square (C. & G. S. b. m. O1) 746.442

Columbus Grove, north side of Sycamore Street, about 33 feet east of Cincinnati, Hamilton & Dayton Ry., on the A. H. Day Building, at the left side of east entrance (in 1899 occupied by post office), on southwest corner of iron plate under iron post; square cut with a cold chisel (C. & G. S. b. m. P1) 770.993

Columbus Grove, Theodore Kunneke Building, southwest corner of Sycamore and High Streets, in water table on the south side of Sycamore Street, about 24 feet west of east corner, at head of stair descending into basement; brass bolt marked with a horizontal line (C. & G. S. b. m. Q1) 775.919

Monroe, Allen County, 2.5 miles north of, on Cincinnati, Hamilton & Dayton Ry., 50 feet below public road crossing, on southeast quarter of culvert over Sycamore Run, southwest corner of second step; chiseled square (C. & G. S. b. m. R1) 790.435

West Cairo, 410 feet west of Cincinnati, Hamilton & Dayton Ry. track, south side of main cross street, on the northwest corner of foundation of dwelling of Charles Wallis, in north face near west angle of water table; brass bolt with horizontal line (C. & G. S. b. m. S1) 814.618

Bath township, midway between West Cairo and Lima, on Cincinnati, Hamilton & Dayton Ry., at east-west road on section line between sections 17 and 18, in front of Henry Boose's residence, in the northeast quarter of viaduct arch, under track, on south end of seventh step from top; chiseled square (C. & G. S. b. m. T1) 836.395

LIMA QUADRANGLE.

Lima south along Cincinnati, Hamilton & Dayton Ry. to Pushada township.

Feet.

Lima, Allen County, Cincinnati, Hamilton & Dayton Ry. station, east side of building, in angle south of main structure, on west end of doorsill stone; chiseled square at time of leveling, entrance to train dispatcher's office (C. & G. S. b. m., U1) ____ 879.

Lima, southeast corner of High and Elizabeth streets, northeast corner of post-office building, in water table, east face, 315 feet south of the north corner and 4.2 feet above the flagging; horizontal cut in center of a 1-inch square cut, one-fourth inch deep, marked "U.S.C.& G.S." (C. & G. S. b. m. V1) ____ 877.

Lima, southwest corner of High and Main streets; top of north fireplug of city hydrant (C. & G. S. b. m., Lima City) ____ 872.

Cridersville, 1.2 miles north of, on Cincinnati, Hamilton & Dayton Ry., on northwest quarter of abutment of bridge 46, over Little Haw Creek, on west end of bridge-seat course, 9 inches north of south face; highest point on square with rounded corners 1.8 inches on a side and lettered "U.S.C.& G.S." (C. & G. S. b. m., W1) ____ 868.

Cridersville, Auglaize County, on Cincinnati, Hamilton & Dayton Ry., 66 feet west from main track and 45 feet north of north side of Main Street, in stone window sill of the Hover Bros.' block; brass bolt marked with horizontal line (C. & G. S. b. m., X1) ____ 892.

Wapakoneta, 0.25 mile north of, on Cincinnati, Hamilton & Dayton Ry., in northeast quarter of bridge 45 over Auglaize River, in bridge-seat course on east part of receding angle, 1.9 meters below top of retaining wall; chiseled square (C. & G. S. b. m., Y1) ____ 866.1

Wapakoneta, east face of county courthouse building, 17 feet from northeast corner of north pillar between basement windows, 3 feet above ground and 16 inches south of the north edge of pillar; brass bolt marked with horizontal line (C. & G. S. b. m., Z1) ____ 898.

Pushada township, on Cincinnati, Hamilton & Dayton Ry., 2 miles south of Wapakoneta, on southeast quarter of bridge 44 over Pushada Creek, on bridge-seat course, 2 feet west of east end of shelf, 7 inches back from edge; elevated point circumscribed by square cut in stone lettered "U.S.C.& G.S." (C. & G. S. b. m., A2) ____ 915.

SIDNEY QUADRANGLE.

Botkins south along Cincinnati, Hamilton & Dayton Ry. to Sidney.

Botkins, Shelby County, north side of main cross street one-fourth mile east of the Cincinnati, Hamilton & Dayton Ry., in top corner of stone foundation of public school building, in south face, 2.5 feet east of west corner, 2.3 feet above ground; brass bolt marked with horizontal line (C. & G. S. b. m. B2) ____ 1,004.

Anna, First Methodist Church building, corner of Pike and Second streets, on the east side of small buttress north of east door, 2.4 feet above ground and 0.49 foot south of north edge of buttress; brass bolt marked with horizontal line (C. & G. S. b. m. C2) ____ 1,030.

Swanders, 0.5 mile north of, northeast quarter of stone culvert dated 1892 under Cincinnati, Hamilton & Dayton Ry. track, top of third step below coping, 5 inches from its south face and 5 inches from east face of next step above; chiseled square (C. & G. S. b. m. D2) ____ 1,013.

	Feet.
Franklin township, on Cincinnati, Hamilton & Dayton Ry., halfway between mileposts 101 and 102 from Cincinnati, lowest point of grade, southeast quarter of culvert, on second step, about 4.3 feet below coping; chiseled square (C. & G. S. b. m. E2)	1,006.033
Sidney, on Cincinnati, Hamilton & Dayton Ry., at southwest quarter of bridge 40 over Cleveland, Cincinnati, Chicago & St. Louis Ry., on northwest corner of bridge seat course, 6 inches from north and west faces; chiseled square (C. & G. S. b. m. F2)	1,000.761
Sidney, northwest corner of courthouse square, 48½ feet above city zero point. The mark was made by burying a sandstone 20 inches square and 2 feet high with another stone 2 feet high and 14 inches square at the bottom and 3 inches square at the top, set on top of the sandstone. Both stones were firmly embedded in the ground up to the top of the second stone, above which is 4 inches of cement in which a cross is cut (C. & G. S. b. m. Sidney City)	957.060
Sidney, county courthouse, on west face of foundation of north vestibule 2 feet 1 inch south of north projecting edge of foundation and 3 feet 5 inches above ground; brass bolt marked with horizontal line (C. & G. S. b. m. G2)	962.675
Clinton township, 1.2 miles south of Sidney, on line of canal and Cincinnati, Hamilton & Dayton Ry., southwest quarter of bridge over canal, on northwest corner of large bridge seat stone 6 inches from each face; chiseled square (C. & G. S. b. m. H2)	961.836

TROY QUADRANGLE.

Sidney south along Cincinnati, Hamilton & Dayton Ry. to Troy.

Kirkwood, Shelby County, on schoolhouse (Pontiac School), on east face, center of second pilaster from south end, on water table, about 2 feet above ground; brass bolt, marked with horizontal line (C. & G. S. b. m. I2)	986.092
Springcreek township, Miami County, on line of Cincinnati, Hamilton & Dayton Ry., midway between Kirkwood and Piqua, on bridge over Bush Creek, east end of west abutment, bridge seat course, 6 inches from east and south faces; chiseled square (C. & G. S. b. m. J2)	934.258
Piqua, Cincinnati, Hamilton & Dayton Ry., culvert 26, over Albino Pike, northeast quarter, on center of east stone of bridge seat course; highest point circumscribed by a 1-inch square lettered "U. S. C. & G. S." (C. & G. S. b. m. K2)	898.948
Piqua, on Pennsylvania R. R., north end of east abutment of bridge over Miami River, top of bridge seat course, 14 inches north of truss and 8 inches back from face; highest point of 4-inch square on side (C. & G. S. b. m. Pennsylvania R. R.)	865.427
Piqua, southwest corner of crossing of Downing Street and Pittsburg, Chicago, Cincinnati & St. Louis Ry., northeast corner of malt house of J. G. Schmidlapp (1889), on water table, 3.9 feet above the sidewalk and 3.28 feet south of corner; brass bolt marked with a horizontal line (C. & G. S. b. m. L2)	876.864
Farrington, on Miami & Erie Canal, 3 miles south of Piqua, lock built by Isaac Van Ness (1835), on west side of tumble on northwest corner of coping stone, 6 inches from either face; chiseled square (C. & G. S. b. m. M2)	855.212

	Feet.
Concord Township, Miami & Erie Canal lock 2.5 miles north of Troy, east jaw of lock, east coping stone of wall, 6 inches from south face and 18 inches from east end of wall; chiseled square (C. & G. S. b. m. N2)	844.5[illegible]
Troy, on Miami & Erie Canal, Troy lock, east jaw, on coping stone, west of east end of wall and 6 inches north of south face; chiseled square (S. & G. S. b. m. O2)	835.4[illegible]
Troy, southwest corner of courthouse, on south face, 2.46 feet from west corner and 3.9 feet above ground; brass bolt marked with a horizontal line (C. & G. S. b. m. P2)	841.0[illegible]
Troy, south side of Miami Street, northeast corner of first house west of Lutheran Church; top of water table (C. & G. S. b. m. Troy City)	837.6[illegible]
Troy, southern limit of town, intersection of Miami & Erie Canal and Cleveland, Cincinnati, Chicago & St. Louis Ry., on east abutment of railroad bridge over canal, on west face of abutment, 4.3 feet above ground and 7.2 feet north of south end of abutment; brass bolt marked with a horizontal line (C. & G. S. b. m. Q2)	831.1[illegible]
Concord township, 1.2 miles south of Troy, on Miami & Erie Canal, south end of lock, east side, 13 feet south of king post at beginning of curve on northwest corner of coping stone; surface circumscribed by square 1.2 inches on a side (C. & G. S. b. m. R2)	827.2[illegible]

DAYTON QUADRANGLE.

Troy south along Cincinnati, Hamilton & Dayton Ry. to Dayton.

Concord township, Miami County, 70 feet below lock, 2.5 miles south of Troy, southwest quarter of masonry of feeder lock, northwest corner of sixth step from top; chiseled square (C. & G. S. b. m. 82)	812.8
Tippecanoe City, on Miami & Erie Canal, east side of Tippecanoe Lock, south end, on center coping stone of wing; chiseled square (C. & G. S. b. m. T2	806.9
Tippecanoe City, north side of Main Street, on first building east of canal, power house of Tippecanoe Electric Light & Water Co., southeast corner, south face, on water table, 5 inches below brick work and 7 inches north of corner; brass bolt, marked with a horizontal line (C. & G. S. b. m. U2)	801.[illegible]
Van Buren township, on Miami & Erie Canal, 2.5 miles below Tippecanoe City, Picayune Lock, east jaw, on coping stone, 12 feet south of south king-pots and 6 inches east of edge of wall; chiseled square (C. & G. S. b. m. V2)	797.[illegible]
Tadmor, Montgomery County, on Miami & Erie Canal, east abutment of steel bowstring girder bridge over canal, northwest corner, on north face, 1 foot east of corner and 3.5 feet above ground; brass bolt, marked with a horizontal line (C. & G. S. b. m. W2)	791.[illegible]
Butler township, on Cincinnati, Hamilton & Dayton Ry., 2.4 miles below Tadmor, on bridge 8 over Poplar Creek, west side of north abutment, first step below bridge seat, 5 inches east of west face of stone and 7 inches north of south face; chiseled square (C. & G. S. b. m. X2)	773.4
Harrison township, on line of the Cincinnati, Hamilton & Dayton Ry., about 1 mile north of Dayton city limits, on north abutment of bridge over Miami River, west side of abutment, 6 inches south of north edge and 17 inches east of west edge; chiseled square (C. & G. S. b. m. Y2)	754.6

	Feet.
Dayton, Cincinnati, Hamilton & Dayton Ry. bridge 2 over Mad River, south abutment, east end, 22 inches west of east end of stone and 6 inches south of north face; chiseled square (C. & G. S. b. m. Z2)	744.420
Dayton, northwest corner of Main and Sixth Streets (city workhouse); point of pyramidal top of stone fence post 3.5 feet above side walk (C. & G. S. b. m. Dayton City)	743.731
Dayton, southwest corner of South Main and West Fifth streets, southeast corner of post office, east face, on water table, 3.9 feet above pavement and 1 foot north of corner; brass bolt, marked with a horizontal line (C. & G. S. b. m. A3)	743.435
Dayton, Cincinnati, Hamilton & Dayton Ry. bridge over Miami River one-third mile south of union station, west pier, north end, on nose of coping stone of pier, midway between sides and 20 inches back from point; chiseled square (C. & G. S. b. m. B3)	744.068

WAYNESVILLE QUADRANGLE.

Dayton south along Cincinnati, Hamilton & Dayton Ry. to Alexandria.

Dayton, 2.5 miles south of, in Van Buren township, on Cleveland, Cincinnati, Chicago & St. Louis Ry., viaduct bridge over highway, midway between Miami River bridge and canal bridge, on north abutment, southeast corner of bridge seat course. 9 inches from either face and 15 feet east of truss; chiseled square (C. & G. S. b. m. E4)	736.673
Dayton, 4 miles south of, on Cincinnati, Hamilton & Dayton Ry., southwest quarter of culvert 39, west end of bridge seat course, 8 inches east of west end and 5 inches south of west face; chiseled square (C. & G. S. b. m. C3)	728.376

MIAMISBURG QUADRANGLE.

Alexandria southwest along Cincinnati, Hamilton & Dayton Ry. and Cleveland, Cincinnati, Chicago & St. Louis Ry. to Middletown.

Alexandria, 0.7 mile south of, in Miami township, on line of Cleveland, Cincinnati, Chicago & St. Louis Ry., 300 feet north of street car power house, on pier of stone culvert over ditch, east end, 10 inches west of east face and 18 inches south of point; chiseled square (C. & G. S. b. m. D4)	722.157
Whitfield, 0.8 mile north of, in Montgomery County, on line of Cincinnati, Hamilton & Dayton Ry., north abutment of bridge 36 over Parthin Creek, east end, on wing wall bridge seat coping, 4.9 feet east from chord and 9 inches from retaining wall; chiseled square (C. & G. S. b. m. D3)	714.310
Carrollton, on Miami & Erie Canal, on tumble of lower Carrollton lock, west side, south end, on second step below coping, 4 inches north of south face and 6 inches west of east face of stone; chiseled square (C. & G. S. b. m. C4)	711.425
Miamisburg, on line of Cleveland, Cincinnati, Chicago & St. Louis Ry., in north end of town, 500 feet north of Enterprise Carriage Works, on bridge 250, over Sycamore Creek, north abutment, west end, on retaining wall, second step below coping, 14 inches east of west face and 6 inches north of south face; chiseled square (C. & G. S. b. m. B4)	707.[illegible]

	Feet.
Miamisburg, 0.2 mile north of station, on Cincinnati, Hamilton & Dayton Ry., east end of north abutment of bridge over Bear Creek on bridge seat course at east end of wing wall, 6 inches from south face and 12 inches from east face; highest point in rounded square, lettered U. S. C. & G. S. (C. & G. S. b. m. E3)	699.729
Miamisburg, on west abutment of road bridge over Miami River at Cincinnati, Hamilton & Dayton Ry. station, on south face of retaining wall, 7 feet west of angle in eighth course of masonry below the coping; brass bolt marked with horizontal line (C. & G. S. b. m. F3)	696.984
Miamisburg, south end of village, about 8 feet east of center of Third Street, north side of Smith Street, 6.72 feet west of center of Cleveland, Cincinnati, Chicago & St. Louis track, 2.4 feet below top of rail on bridge seat course of masonry; chiseled square (C. & G. S. b. m. A4)	705.123
Miamisburg, 2.2 miles south of, on Cincinnati, Hamilton & Dayton Ry., culvert 32, northeast quarter, fourth step below bridge seat course, 3 inches west of east face and 6 inches north of south face; chiseled square (C. & G. S. b. m. G3)	693.755
Franklin, 2 miles north of, Cleveland, Cincinnati, Chicago & St. Louis Ry. culvert 223, over race from lock, south abutment, second stone from east end of bridge seat course, 7 inches south of north face and 6 inches west of east face; chiseled square (C. & G. S. b. m. Z3)	704.111
Carlisle, 0.5 mile north of, Warren County, Cincinnati, Hamilton & Dayton Ry. culvert 31 over creek, north abutment, east end, on bridge seat course, 6 inches from east face, 12 inches north of south face; chiseled square (C. & G. S. b. m. H3)	692.078
Franklin, plant of Franklin Water Works, northwest corner of Sixth Street at Cleveland, Cincinnati, Chicago & St. Louis Ry. crossing, southeast corner of water table; highest point of rounded square exactly in angle (C. & G. S. b. m. I3)	688.965
Carlisle, 2.2 miles south of, Cincinnati, Hamilton & Dayton Ry. bridge 30 over Big Twin Creek, on south pier of two on east end, center of nose, 15 inches back from point; chiseled square (C. & G. S. b. m. J3)	677.655
Franklin, 1 mile south of station, Miami County, Cleveland, Cincinnati, Chicago & St. Louis Ry. bridge 254 over Clear Creek, south abutment, west side on second course below top of retaining wall, 3 feet above bridge seat course, 5 inches from both west and north faces; chiseled square (C. & G. S. b. m. Y3)	684.451
Poast Town, 0.5 mile south of, Butler County, Cincinnati, Hamilton & Dayton Ry. bridge 26 over Brown Run, on east end of wing wall, north abutment, first step below bridge seat course, southeast corner of stone; chiseld square (C. & G. S. b. m. K3)	658.288
Middletown, 2.8 miles north of, Cleveland, Cincinnati, Chicago & St. Louis Ry. culvert 270, south abutment, east end of bridge seat course, 13 inches south of north face and 10 inches west of east face; chiseled square (C. & G. S. b. m. X3)	674.697
Middletown, 400 feet north of station, in village of Keno, on Cincinnati, Hamilton & Dayton Ry., north abutment of culvert 21, east end, on first step below bridge seat course, 6 inches west of east face and 6 inches north of south face; chiseled square (C. & G. S. b. m. L3)	643.037

Middletown, eastern part of city, about 493 feet west of Cleveland, Cincinnati, Chicago & St. Louis Ry. track, southwest corner of Third and Grimes streets, on east face of Kimball block, 12 inches south of north corner and 3.5 feet above flagging; brass bolt marked with a horizontal line (C. & G. S. b. m. M3)	Feet. 666.502

MASON QUADRANGLE.

Middletown southwest along Cincinnati, Hamilton & Dayton Ry. to Rockdale.

Excello Mills, Butler County, on Miami & Erie Canal lock, west wall of tumble, north end, on end coping stone 6 inches from north face and 11 inches from east face; chiseled square (C. & G. S. b. m. W3)	638.232
Trenton, 1 mile northeast of, Cincinnati, Hamilton & Dayton Ry. bridge over Hill Creek, on east end of pier, in center of nose, 18 inches back from point; chiseled square (C. & G. S. b. m. N3)	633.008
Le Sourdsville, 328 feet southwest of, on line of Cincinnati, Hamilton & Dayton Ry., on north retaining wall, east end of aqueduct over canal, opposite north end of railway bridge over creek, on third stone from end, 16 inches from south face and 8 inches from east face; highest point in square lettered "U.S.C.&G.S." (C. & G. S. b. m. V3)	624.938
Busenbark, 1 mile south of, 0.8 mile northeast of Overpeck, on line of the Cincinnati, Hamilton & Dayton Ry., on arch culvert about 66 feet south of milepost C. 31, on northeast corner of stone, about 6 inches from either face; chiseled square (C. & G. S. b. m. O3)	635.355

Flockton southeast along Cincinnati, Hamilton & Dayton Ry. to Glendale.

Flockton, 1,000 feet west of, on culvert 34, west abutment, north end; highest point in square 2½ inches on a side (C. & G. S. b. m. Pennsylvania R. R. No. 23)	605.650
Jones, 1.5 miles north of, on line of the Cincinnati, Hamilton & Dayton Ry., 4.5 miles south of Hamilton, on viaduct bridge 11, north abutment, east end, on second step below bridge-seat course, on southeast corner of stone, 6 inches from either face; chiseled square (C. & G. S. b. m. G4)	638.992
Port Union, in culvert 32, north abutment, east end; highest point in square 2.5 inches on a side (C. & G. S. b. m. Pennsylvania R. R. No. 21)	596.090
Crescentville, 1 mile north of, on culvert 30, north abutment, east end; highest point in square 2.5 inches on a side (C. & G. S. b. m. Pennsylvania R. R. No. 20)	589.408
Crestvue, 0.2 mile south of, Cincinnati, Hamilton & Dayton Ry., stone culvert over Carmins Creek, southwest quarter, on end coping stone, 10 inches east of west face and 5 inches north of south face; chiseled square (C. & G. S. b. m. H4)	646.878
Crescentville, 0.5 mile south of, on railroad culvert 29, on north abutment, east end; highest point in square 2.5 inches on a side (C. & G. S. b. m., Pennsylvania R. R., No. 19)	579.163
Port Union, 2 miles south of, on bridge 27 over creek, east end of north abutment; highest point in square 2.5 inches on a side (C. & G. S. b. m. Pennsylvania R. R. No. 17)	573.704

Glendale, 1 mile south of, Cincinnati, Hailton & Dayton Ry., culvert 9, northwest quarter, first step below bridge-seat course, 5 inches east of west face and 10 inches north of south face; chiseled square (C. & G. S. b. m. I4) ---- Feet. 607.200

HAMILTON QUADRANGLE.

Rockdale south along Cincinnati, Hamilton & Dayton Ry. to Flockton.

Rockdale, 0.2 mile north of, on Cincinnati, Hamilton & Dayton Ry., west end of stone culvert covered by roadbed, on coping stone, 8 inches from south face and 6 inches from west face; chiseled square (C. & G. S. b. m. U3) ---- 630.346

Hamilton, 2.5 miles north of station, Cincinnati, Hamilton & Dayton Ry. bridge 16 over Miami River, on retaining wall at north end of bridge seat, 4 inches from south and east faces; chiseled square (C. & G. S. b. m. P3) ---- 597.651

Woodsdale, 0.25 mile north of, on Cincinnati, Hamilton & Dayton Ry., on south abutment of bridge over Campbells Creek, west end of bridge seat course, on large stone, 6 inches from north and west faces; highest point in circumscribed 1-inch square (C. & G. S. b. m T3) ---- 616.951

Hamilton, Butler County, on Cincinnati, Hamilton & Dayton Ry., 0.9 mile north of Union Station, at three-arched stone bridge over Old River, on east side, north end, on second step below coping of wing wall, 5 inches from both east and south faces; highest point in circumscribed square (C. & G. S. b. m. Q3) ---- 591.098

Hamilton, on foundation of courthouse, northeast corner, in reentrant angle, 15 inches east of east pilaster of basement door and 3 inches north of wall, being north half of west edge of surface inclosed in 2.5-inch square lettered "Datum, city elevation 100[1]" (C. & G. S. b. m. Hamilton city) ---- 601.631

Hamilton, south side of High Street, in east face of courthouse, at its northeast corner, 3.9 feet south of corner, which is cornerstone of building, on first stone south of cornerstone; brass bolt marked with horizontal line (C & G. S. b. m. R3) ---- 605.317

Hamilton, in southeast quarter of city, south face of Cincinnati, Hamilton & Dayton station, on water table 33.5 inches from southwest corner and 2 inches above brick paving; chiseled square (C. & G. S. b. m. S3) ---- 596.001

Hamilton, 2 miles south of, on east end of small stone culvert opposite telegraph pole 745, Pennsylvania R. R., being highest point on square 2.25 inches on a side (C. & G. S. b. m. telegraph pole No. 745) ---- 610.259

Hamilton, 2.2 miles south of, Cincinnati, Hamilton & Dayton R. R. culvert 13 (cattle pass), north side, east end, on fifth step below bridge seat course, 5 inches from south and east faces; chiseled square (C. & G. S. b. m. F4) ---- 602.340

Flockton, 2 miles north of, on culvert 35a, east side, north end; highest point of square (C. & G. S. b. m. Pennsylvania R. R. No. 24) ---- 613.166

WEST CINCINNATI QUADRANGLE.

Ivorydale south to Cincinnati, thence west to North Bend.

	Feet.
Ivorydale, suburb of Cincinnati, on Cincinnati, Hamilton & Dayton Ry., 100 feet south of station, on north abutment of bridge 4 over Mill Creek, west end of bridge-seat course, 6 inches north of obtuse angle of wing wall; chiseled square (C. & G. S. b. m. M4)	499.485
Winston Springs, on Cleveland, Cincinnati, Chicago & St. Louis Ry., on north abutment of bridge over Mill Creek, west end, on coping stone. The original disk has been removed; the part taken as the bench mark is highest point of ring cut in stone (C. & G. S. b. m. U.S.G.S. No. 498)	497.974
Cincinnati, north part of city, on Miami & Erie Canal, 0.5 mile north of Clifton Springs, on Spring Grove, tumble of canal, on north wall, second step below bridge seat, 6.6 feet west of west side of wooden bridge, 5 inches from face of stone and 6 inches from end of stone; chiseled square (C. & G. S. b. m. Q4)	541.285
Cincinnati, north part of city, on Baltimore & Ohio R. R., on south abutment of bridge 3 over Spring Grove Avenue, east end, on first course below bridge-seat course, on top of first course of sandstone above limestone, on its northeast corner, 6 inches from either face; chiseled square (C. & G. S. b. m. N4)	500.969
Cincinnati, west part of city, Baltimore & Ohio R. R. viaduct 90 over Gist Street, north abutment, west end, on second step and second course below bridge-seat course, 5 feet 6 inches below top of rail, 16 feet west of rail, 6 inches from face of and 8 inches from end of stone; chiseled square (C. & G. S. b. m. O4)	491.656
Cincinnati, northeast corner of Richmond and Freeman streets, on extreme southwest corner of water table of building; chiseled square (C. & G. S. b. m. Cincinnati City)	504.316
Cincinnati, east end of Richmond Street, east side of Central Avenue, 4.7 feet south of prolongation of north curb line of Richmond Street, on southwest corner of four-story brick building owned by Mrs. Sarah Neare, on south end of doorstone, 6 inches from either face corner; square cut (C. & G. S. b. m. P4)	545.301
Cincinnati, courthouse, 5.37 feet directly above No. 1 or T; horizontal scratch on a silvered metal plate set flush with the masonry and covered by an iron plate, locked in place (C. & G. S. b. m. Reference mark to Cincinnati City No. 1)	545.349
Cincinnati, northeast corner of Fifth and Main streets, east side post-office building, north end of third window base from southeast corner, 8 inches south from pilaster base supporting columns, 8 inches back (west) from edge of stone, west of deep area way approached only through window of building or by aid of plank; brass bolt leaded vertically, marked with circle (C. & G. S. b. m. Y4)	553.078
Cincinnati, northeast corner of Front and Butler streets, on west end pier of Newport Bridge, beside Louisville & Nashville R. R. bridge, on third course above ground, 10 inches north of south face and 4.4 feet above pavement; brass bolt marked with a horizontal line. (C. & G. S. b. m. Z4)	490.818

Cincinnati, north entrance to waterworks building on Front Street, 0.28 miles above Louisville & Nashville bridge, on west side of building, on iron doorsill, southwest end, 5 inches north of south jamb of door and 5 inches back from front edge of sill; center of cross cut diagonally across corrugations. This bench mark is said by city authorities and United States Gage Book to be at elevation corresponding to 60.389 on gage (C. & G. S. b. m. Gage B M) -- Feet. 491.633

Cincinnati, west part of city, on east abutment of lower road bridge at Eighth Street over Mill Creek, south side, 71 feet east of west end of this abutment and 15.5 feet west of east end, and 2.17 feet below coping; brass bolt marked with a horizontal line. An arrow cut on vertical face of coping points downward and toward the bench (C. & G. S. b. m. U4) ---- 493.987

Cincinnati, west part of city, on bank of Ohio River, between railroad tracks and Front Street, in vertical plane with west wall of first house (No. 2658) west of Lutheran Church "Deutsche Ves. Ev. Prot. Martini Kirche A. D. 1892," on coping of heavy retaining wall, called "Big Four wall," about 160 feet east of west end of wall; chiseled square (C. & G. S. b. m. V4) ---- 504.328

Cincinnati, west end of Cleveland, Cincinnati, Chicago & St. Louis Ry. retaining wall between Front Street and railroad tracks, 5.7 feet below top of coping and 6 inches north of south face of wall; center of indented point surrounded by triangle (C. & G. S. b. m. U.S.H.) ---- 499.589

Sedamsville, intersection of Delhi Avenue and street car tracks, on cement walk near wall at northeast corner of Hartman's saloon, 8 inches west of corner of water table and 2 inches out from wall; chisel mark later enlarged to square (C. & G. S. b. m. U.S.G.S.) ---- 491.676

Cincinnati, southwest quarter of city, on Liston Avenue, opposite No. 3538, south side station of Cleveland, Cincinnati, Chicago & St. Louis Ry., on northeast corner of building, north face, on first course of stone below water table, 3.9 feet above sidewalk, and 4 inches west of east corner; brass bolt marked with a horizontal line (C. & G. S. b. m. W4) ---- 494.482

St. Joseph, 8.5 miles west of Cincinnati, on Cleveland, Cincinnati, Chicago & St. Louis Ry., on north bank of Ohio River, 48 feet west of southwest corner of station and 56.25 feet south of south face of station, 4.8 feet south of south edge and 2.7 feet below top of retaining wall of Cleveland, Cincinnati, Chicago & St. Louis Ry., on east end of stone box culvert under road crossing culvert lying between Baltimore & Ohio Southwestern and Cleveland, Cincinnati, Chicago & St. Louis tracks and parallel with them; chiseled square on projecting part of south wall supporting covering stone (C. & G. S. b. m. X4) ---- 485.915

Delhi, 81 feet west of west side of Baltimore & Ohio station, stone supposed to be bench mark No. LXV of transcontinental line of 1879, nothing resembling bench identification mark was found, but a portion of the stone had been chipped off. The elevation of a low point in an irregular square was taken. Stone forms a foundation stone of Cleveland, Cincinnati, Chicago & St. Louis station platform and is below plank (C. & G. S. b. m. Canal stone) ---- 487.791

Delhi, 2 miles west of, on coping stone of double arch culvert, north side, over buttress between east arch over Muddy Creek and west arch over a railroad track, 85 feet east of west end of coping, 9 inches east of north face and 2.2 feet above top of rail; chiseled square (C. & G. S. b. m. B5)	Feet. 494.157
North Bend, Hamilton County, on line of Cleveland, Cincinnati, Chicago & St. Louis Ry., on viaduct bridge opposite Baltimore & Ohio Southwestern R. R. station, on east abutment, west face, 23.6 feet north of south end and 3.9 feet above ground; brass bolt marked with horizontal line (C. & G. S. b. m. C5)	491.765
Ohio-Indiana State line, on line of Baltimore & Ohio R. R., 2 miles east of Lawrenceburg, Ind., on railroad bridge over Miami River, east abutment, north side, 5 inches south of north face and 18 inches east of west end; chiseled square (C. & G. S. b. m. D5)	482.633
Lawrenceburg, Dearborn County, on west side of Short Street, between Baltimore & Ohio Southwestern Ry. and High Street, on People's National Bank Building, north wall, 2.75 feet west of northeast corner and 3.9 feet above ground, in water table; brass bolt marked with a horizontal line (C. & G. S. b. m. E5)	483.941

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 477

RESULTS OF SPIRIT LEVELING IN WEST VIRGINIA

1909 AND 1910

R. B. MARSHALL, CHIEF GEOGRAPHER

WORK DONE IN COOPERATION WITH THE STATE OF WEST VIRGINIA

WASHINGTON
GOVERNMENT PRINTING OFFICE
1911

CONTENTS.

ILLUSTRATION.

GEOLOGICAL SURVEY BENCH MARKS.

A, Tablet used in cooperating States. The State name is inserted at *G*.
B and *D*, Copper temporary bench mark, consisting of a nail and copper washer.
A, *C*, and *E*, Tablets for stone or concrete structures.
F, Iron post used where there is no rock.

RESULTS OF SPIRIT LEVELING IN WEST VIRGINIA, 1909 AND 1910.

R. B. MARSHALL, Chief Geographer.

INTRODUCTION.

Corrections.—The following results of spirit leveling are supplemental to and accord with the elevations contained in Bulletin 399 and are in agreement with the 1903 adjustment of precise leveling. Corrections to Bulletin 399 should be noted as follows:

Page 13, Williamsport, the bench mark described has been destroyed. A new bench mark established by the Cumberland Valley Railroad Co. in the top of the south heading of the new culvert has an elevation of 363.094 feet.

Page 17, Newburg, the bench mark described has been destroyed. A new one has been established, the description of which is the same as that of the old bench mark except that the tablet is of aluminum and has been set about 75 feet across a creek. Its elevation is 1,230.017 feet.

Pages 59 and 60, elevations in Gilbert 15′ quadarangle have been corrected by leveling in 1909 and 1910. The new values are given in this publication, pages 17–20.

Page 60, name of Oceana special quadrangle has been changed to Pineville quadrangle, and elevations of bench marks 6 and 7 miles, respectively, east of Cyclone, have been corrected as given in this publication, page 30.

Page 64, bench mark at Arvilla has been disturbed and the elevation as given is unreliable.

Personnel.—The field work of 1909 and 1910 was done under the supervision of Frank Sutton, geographer, under the general direction of R. B. Marshall, chief geographer. Credit is given to the different levelmen in the introduction to each list. The office work of computation, adjustment, and preparation of lists was done mainly by S. S. Gannett, geographer, and D. H. Baldwin, topographer, under the general direction of E. M. Douglas, geographer.

Classification.—The elevations are classified as precise or primary according to the methods employed in their determination. For precise level lines instruments and rods of the highest grade are used, each line is run both forward and backward, and every precaution is taken to guard against error. The allowable divergence between the forward and the backward lines in feet is represented by the formula $0.017\sqrt{D}$, in which D is the distance in miles between bench marks. For primary lines standard Y levels are used; lines are run in circuits or are closed on precise lines, with an allowable closing error in feet represented by $0.05\sqrt{D}$, in which D is the length of the circuit in miles, sufficient care being given to the work to maintain this standard. For levels of both classes careful office adjustments are made, the small outstanding errors being distributed over the lines.

Bench marks.—The standard bench marks are of two forms. The first form is a circular bronze or aluminum tablet (*C* and *E*, Pl. I) 3½ inches in diameter and one-quarter inch thick, having a 3-inch stem, which is cemented in a drill hole in solid rock in the wall of some public building, a bridge abutment, or other substantial masonry structure. The second form (*F*, Pl. I), used where masonry or rock is not available, consists of a hollow wrought-iron post 3½ inches in outer diameter and 4 feet in length. The bottom is spread out to a width of 10 inches in order to give a firm bearing on the earth. A bronze or aluminum-bronze cap is riveted over the top of the post, which is set about 3 feet in the ground. A third style of bench mark with abbreviated lettering (*B* and *D*, Pl. I) is used for unimportant points. This consists of a special copper nail, 1½ inches in length, driven through a copper washer seven-eighths inch in diameter. The tablets as well as the caps on the iron posts are appropriately lettered, and State cooperation is indicated by the addition of the State name (*G*, Pl. I).

The numbers stamped on the bench marks described in the following pages represent the elevations to the nearest foot as determined by the levelman. These numbers are stamped with three-sixteenths-inch steel dies on the tablets or post caps, to the left of the word "feet." The office adjustment of the notes and the reduction to mean sea level datum may so change some of the figures that the original markings a e 1 or 2 feet in error. It is assumed that engineers and others who have occasion to use the bench-mark elevations will apply to the Director of the United States Geological Survey, at Washington, D. C., for the adjusted values, and will use the markings as identification numbers only.

Datum.—All United States Geological Survey elevations are referred to mean sea level, which is the level that the sea would assume if the influence of winds and tides were eliminated. This level is not the elevation determined from the mean of the highest and the lowest tides, nor is it the half sum of the mean of all the high tides and the mean of all the low tides, which is called the half-tide level. *Mean sea level is the average height of the water, all stages of the tide being considered.* It is determined from observations made by means of tidal gauges placed at stations where local conditions, such as long, narrow bays, rivers, and like features, will not affect the height of the water. To obtain even approximately correct results these observations must extend over at least one lunar month, and if accuracy is desired they must extend over several years. At ocean stations the half-tide level and the mean sea level usually differ but little. It is assumed that there is no difference between the mean sea level as determined from observations in the Atlantic Ocean, the Gulf of Mexico, or the Pacific Ocean.

The connection with tidal stations for bench marks in certain areas that lie at some distance from the seacoast is still uncertain, and this fact is indicated by the addition of a letter or word to the right of the word "Datum" on tablets or posts. For such areas corrections for published results will be made from time to time as the precise level lines of the United States Geological Survey or other Government organizations are extended.

Topographic maps.—Maps of the following quadrangles wholly or partly in West Virginia have been published by the United States Geological Survey up to June 1, 1911. They may be obtained for 5 cents each or $3 a hundred on application to the Director of the Survey at Washington, D. C.:

Accident (Md.-Pa.-W. Va.).
Antietam (Md.-Va.-W. Va.).
Arnoldsburg.
Athalia (Ohio-W. Va.).
Belington.
Belleville (W. Va.-Ohio).
Beverly (W. Va.-Va.).
Blacksville (W. Va.-Pa.).
Bruceton (W. Va.-Pa.).
Buckhannon.
Burnsville.
Cameron (W. Va.-Ohio-Pa.).
Centerpoint.
Charleston.
Charleston special.
Christiansburg (Va.-W. Va.).
Clarington (Ohio-W. Va.).
Clarksburg.
Clay.
Clendenin.
Dublin (Va.-W. Va.).
Elizabeth.
Elkins.
Fairmont.
Fayetteville.
Flintstone (Md.-W. Va.-Pa.).
Franklin (W. Va.-Va.).
Frostburg (Md.-W. Va.-Pa.).
Gassaway.
Glenville.
Glenwood (W. Va.-Ohio).
Guyandot (W. Va.-Ohio).
Hancock (W. Va.-Md.-Pa.).
Harpers Ferry (Va.-W. Va.-Md.)
Harrisville.
Hinton.
Holbrook.
Huntersville.
Huntington (W. Va.-Ohio-Ky.).
Kanawha Falls.
Kenna.
Keno (Ohio-W. Va.).
Kenova (Ky.-W. Va.-Ohio).
Kingwood.
Lewisburg (Va.-W. Va.).
Littleton (W. Va.-Pa.).
Mannington (W. Va.-Pa.)
Marietta (Ohio-W. Va.).
Midkiff.
Milton.
Monterey (Va.-W. Va.).
Montgomery.
Morgantown (W. Va.-Pa.).
New Martinsville (W. Va.-Ohio).
New Matamoras (Ohio-W. Va.).
Nicholas.
Oakland (Md.-W. Va.).
Oceana (W. Va.-Va.-Ky.).
Otter.
Parkersburg (Ohio-W. Va.).

Parsons.
Pawpaw (Md.-W. Va.-Pa.).
Peytona.
Philippi.
Piedmont (W. Va.-Md.).
Pocahontas (Va.-W. Va.).
Point Pleasant (W. Va.-Ohio).
Pomeroy (Ohio-W. Va.).
Raleigh.
Ravenswood (W. Va.-Ohio).
Ripley.
Romney (W. Va.-Va.-Md.).
St. Albans.
St. George.
St. Marys (W. Va.-Ohio).
Spencer.
Staunton (Va.-W. Va.).
Steubenville (Ohio-W. Va.-Pa.).
Sutton.
Sutton special.
Tazewell (Va.-W. Va.).
Thornton.
Vadis.
Walton.
Warfield (W. Va.-Ky.-Va.).
Wayne.
Wellsville (Ohio-W. Va.-Pa.).
Weston.
West Union.
Wheeling (W. Va.-Ohio-Pa.).
Winchester (Va.-W. Va.).
Winfield.
Woodstock (Va.-W. Va.).

PRECISE LEVELING.

Ingleside, Packs Ferry, and Peterstown 15′ quadrangles (Dublin, Hinton, and Pocahontas 30′ quadrangles).

MERCER AND SUMMERS COUNTIES.

The following elevations make up the West Virginia portion of the unadjusted results of a line of precise levels run from Hinton, W. Va., south along highways to Glenlyn, Va., thence west along Norfolk & Western Railway to Graham, Va., based upon an elevation at Hinton determined by precise leveling. The leveling was done by two parties, which joined at a point 2 miles west of Oakvale. Yard rods and prism levels were used. The total length of the double line is 57.8 miles and the total divergence was 0.155 foot. For the elevations at Glenlyn and Graham, Va., see the Virginia list.

The leveling was done in 1909, in the Packs Ferry and Peterstown 15′ quadrangles by C. H. Semper, and in the Ingleside quadrangle by T. A. Green.

PACKS FERRY 15′ (HINTON 30′) QUADRANGLE.

Hinton south along highway to point 1 mile south of Crumps Bottom.

	Fee[illegible]
Hinton, in northwest corner of Chesapeake & Ohio Ry. station; aluminum tablet stamped "1386"	1,385.[illegible]
Belleview, 1 mile south of, east of road; point on rock marked "U. S. □ B. M. 1440"	1,440.0[illegible]
Belleview, 3.8 miles south of, 350 feet east of road, at J. N. Hayne's farmhouse, in cement well curb; aluminum tablet stamped "1409"	1,408.96
Belleview, 5.7 miles south of, in southwest corner of J. H. Blankenship's house; aluminum tablet stamped "1402"	1,402.20
Belleview, 6.7 miles south of, west of road, 800 feet south of Webb's house; spike in root of sycamore tree	1,395.62
Belleview, 7.8 miles south of, east of road, 100 feet north of sawmill site; large rock marked "U. S. □ B. M. 1427"	1,426.71

	Feet.
Belleview, 8.8 miles south of, in stone chimney of E. F. Farley's house; aluminum tablet stamped "1446"	1,446.136
Warford, 150 feet south of store, east of road; large rock marked "U. S. □ B. M. 1411"	1,410.66
Warford, 1 mile south of, north margin of road; rock 7 by 5 feet marked "U. S. □ B. M. 1453"	1,453.096
Warford, 2.9 miles south of, in stone chimney of J. H. Dickison's house; aluminum tablet stamped "1446"	1,446.143
Crumps Bottom, in southwest corner of G. W. Harmon's house; aluminum tablet stamped "1510"	1,510.063
Crumps Bottom, 1 mile south of, east margin of road, 450 feet below falls; stone marked "U. S. □ B. M. 1451"	1,451.01

PETERSTOWN 15′ (DUBLIN 30′) QUADRANGLE.

Point 1 mile south of Crumps Bottom south along highway to Glenlyn, Va., thence west along Norfolk & Western Ry. to point 1.9 miles west of Oakvale.

Crumps Bottom, 2 miles south of, east margin of road, 75 feet north of very large bowlder; rock 5 by 5 feet marked "U. S. □ B. M. 1441"	1,441.36
Mercer, salt well, 40 feet south of road leading into store yard, in center of highway, in large stone; aluminum tablet stamped "1470"	1,470.466
Mercer, 2 miles south of salt works, on west margin of road, 300 feet north of log house and barn; rock marked "U. S. □ B. M. 1483"	1,483.39
Mercer, 3.2 miles south of salt works, 10 feet southeast of Dicks Hollow crossing, 250 feet north of L. R. French's house, on west margin of road, in top of sand rock; aluminum tablet stamped "1510"	1,510.007
Mercer, 5.3 miles south of salt works, at Bluff post office boat landing, 20 feet west of river, 15 feet east of highway, in large flat rock; aluminum tablet stamped "1466"	1,465.931
Mercer, 6.3 miles south of salt works, 500 feet south of State line, on west margin of highway by small drain; low stone marked "U. S. □ B. M. 1490"	1,489.80
Mercer, 8.4 miles south of salt works, 1,400 feet south of schoolhouse, east margin of road; square cut on rock marked "U. S. B. M. 1496"	1,495.83
Mercer, 8.7 miles south of salt works, in southwest corner of Dr. G. A. Shumate's brick house; aluminum tablet stamped "1571"	1,571.564
Mercer, 10.3 miles south of salt works, at east end of old railroad grade, where grade crosses highway, on west margin of road; large rock marked "U. S. □ B. M. 1505"	1,504.65
(For elevations at Glenlyn, Va., see Virginia list.)	
Wills, in front of station; top of rail	1,624.5
Glenlyn, 3 miles west of, 100 feet west of milepost "C 364," in top of north end on east side of bridge abutment; aluminum tablet stamped "1644"	1,643.830
Oakvale, in front of station; top of rail	1,712.2
Oakvale, 45 feet west of station, 20 feet north of track, in top of railroad culvert; aluminum tablet stamped "1712"	1,712.199
Oakvale, 1.9 miles west of, 2.3 miles east of Hardy, opposite milepost "C 358" 2 feet north of east bound track; top of rail set vertically in ground.	1,782.35

INGLESIDE 15′ (POCAHONTAS 30′) QUADRANGLE.

Point 1.9 miles west of Oakvale west along Norfolk & Western Ry. to Bluefields.

Hardy, 0.2 mile east of, 250 feet west of milepost 351, north of railroad, in west edge of sandstone culvert; aluminum tablet stamped "1868"	1,867.860
Hardy, in front of station; top of rail at crossing	1,884.22
Ingleside, 0.8 mile east of, at milepost 352, on south end of east abutment of railroad bridge 829; chiseled square	1,917.98

	Feet.
Ingleside, in front of station; top of rail	1,950.17
Ingleside, 0.2 mile west of, 300 feet east of milepost 353, on west end of sandstone culvert; chiseled square	1,959.41
Blake, 200 feet southwest of signal tower, in south end of east abutment of railroad bridge 832; aluminum tablet stamped "2009"	2,009.607
Ada, 1.6 miles east of, 300 feet west of milepost 357, north of railroad, 20 feet south of gate across trail, in limestone rock; aluminum tablet stamped "2155"	2,154.887
Ada, in front of station; top of rail	2,223.7
Bluefields, 3.1 miles east of, 100 feet east of milepost 360, on north side of railroad, in west end of sandstone culvert; aluminum tablet stamped "2331"	2,330.968
Bluefields, 2.1 miles east of, 50 feet west of milepost 361, on rock; chiseled square	2,413.20
Bluefields, 100 feet south of station, at front entrance to New Altamont Hotel, in first step above pavement; aluminum tablet stamped "2563"	2,563.129
Bluefields, in front of station; top of rail	2,558.43

PRIMARY LEVELING.

Iaeger, Ingleside, Pocahontas special, and Welch 15′ quadrangles (Pocahontas, Raleigh, and Tazewell 30′ quadrangles).

McDOWELL, MERCER, AND WYOMING COUNTIES.

The following elevations were determined by primary leveling extended from Graham, Va., and Catlettsburg, Ky., points of the precise level net. For additional elevations in West Virginia in the Princeton and Pocahontas quadrangles refer to the precise-level list, Hinton, W. Va., to Graham, Va. (pp. 8–10).

Most of the leveling was done in 1909, in the Iaeger and Welch quadrangles by T. A. Green and C. H. Semper; in the Pocahontas special quadrangle by Green, Semper, and S. E. Taylor; and in the Ingleside quadrangle by Semper. Additional leveling in the Iaeger and Welch quadrangles was done in 1910 by S. E. Taylor.

INGLESIDE 15′ (POCAHONTAS 30′) QUADRANGLE.

Montcalm north along Norfolk & Western Ry. and Virginian Ry. to Giatto.

	Feet.
Montcalm, 1.3 miles north of, 85 feet south of milepost 10, 180 feet south of south end of tunnel, 20 feet east of track, in large rock; aluminum tablet stamped "2210"	2,210.375
Rock, in front of station; top of rail	2,221.1
Rock, 1.8 miles north of, 570 feet north of milepost 13, east side, south end, in top of railroad culvert; aluminum tablet stamped "2277"	2,276.762
Matoaka, 513 feet east of station, in east end of face of south abutment of Virginian Ry. overhead crossing; aluminum tablet stamped "2362"	2,362.448
Matoaka, in front of Norfolk & Western Ry. station; top of rail	2,362.6

POCAHONTAS SPECIAL 15′ (POCAHONTAS 30′) QUADRANGLE (WEST VIRGINIA PORTION).

Point 1.1 miles east of East Vivian east along Norfolk & Western Ry. to State line.

East Vivian, in front of station; top of rail	1,515.5
East Vivian, 1.1 miles east of, in north end of east abutment of railroad bridge 883; aluminum tablet stamped "1555"	1,554.837

	Feet.
Eckman, in front of station; top of rail	1,593.4
Eckman, 0.3 mile east of, at milepost 388, north end of east abutment of railroad bridge 880; chiseled square	1,604.00
Keystone, front entrance to Alahambra Hotel, in east end of step above pavement; aluminum tablet stamped "1645"	1,645.311
North Fork, 1 mile east of, 200 feet east of milepost 385, on north end of bridge seat of west abutment of railroad bridge 874; chiseled square	1,759.96
Powhatan, in front of station; top of rail	1,799.8
Upland, 50 feet south of railroad, at northwest corner of footbridge over Elkhorn Creek, 100 feet north of company store; aluminum tablet stamped "1843"	1,843.296
Elkhorn, at milepost 383, on west end of north abutment of footbridge over Elkhorn Creek; chiseled hole	1,881.87
Elkhorn, 1 mile east of, at milepost 382, on north end of bridge seat of east abutment of railroad bridge 867; chiseled square	1,948.45
Ennis, west of station, at road crossing; top of rail	1,995.9
Ennis, 0.6 mile east of, 950 feet east of milepost 381, in north end of east abutment of arch over Elkhorn Creek and wagon road; aluminum tablet stamped "2032"	2,031.834
Lick Branch, in front of station; top of rail	2,051.6
Lick Branch, at road crossing just east of company store, in cut; copper bolt marked "B. M. No. 64"	2,058.25
Maybeury, in front of station; top of rail	2,171.0
Coaldale, 350 feet west of post office, 125 feet east of telegraph station, north of railroad, in sandstone ledge; aluminum tablet stamped "2339"	2,339.416
Coaldale, 0.4 mile east of, at top of divide over long tunnel, 12 feet south of property line post in center of divide; top of rail section	2,652.00
Ruth, in front of station; top of rail	2,392.3
Ruth, 0.6 mile east of, on southeast corner of concrete foundation for block signal; chiseled square	2,358.23
Cooper, 300 feet west of tunnel, on north end of east abutment of railroad bridge 854; chiseled square	2,309.28
Bluestone, in front of station; top of rail	2,285.3
Bluestone, in north end of east abutment of railroad bridge 851; aluminum tablet stamped "2283"	2,283.248
Nemours, road crossing at mail crane; top of rail	2,296.5
Nemours, 300 feet west of milepost 372, in north end of east abutment of railroad bridge 848; aluminum tablet stamped "2300"	2,299.616
Flattop, 300 feet west of milepost 371, on north end of east abutment of railroad bridge 844; chiseled square	2,309.10

Cooper northeast along Norfolk & Western Ry. to Montcalm.

Cooper, 300 feet west of tunnel, on north end of east abutment of railroad bridge 854; chiseled square marked "No. 44 U. S. B. M. 2309"	2,309.382
Cooper, 0.6 mile north of, 60 feet north of milepost 2, 4 feet west of track, in side cut; marked square on top of rock	2,264.53
Bramwell, in front of station; top of rail	2,252.7
Simmons, in front of station; top of rail	2,249.6
Simmons, 0.1 mile north of, 20 feet east of track, in top of northwest foundation of water tank; aluminum tablet stamped "2247"	2,247.330
Flipping, 0.2 mile south of, in top of west abutment on north side of highway bridge over Bluestone River; aluminum tablet stamped "2225"	2,224.777
Flipping, in front of station sign; top of rail	2,220.9
Montcalm, opposite station; top of rail	2,213.8

Giatto northwest along Virginian Ry. to Micajah tunnel.

	Feet.
Giatto, in front of station; top of rail	2,373.1
Giatto, 1.1 miles west of, 55 feet west of milepost 18, 6 feet south of Norfolk & Western Ry., in top of rock; aluminum tablet stamped "2417"	2,416.932
Clark, in south foundation pier of Virginian Ry. water tank; aluminum tablet stamped "2487"	2,487.121
Clark, in front of station; top of rail	2,522
Clark, 0.7 mile northwest of, 8 feet west of railroad, on sandstone ledge; chiseled square	2,466.93
Clark, 3 miles northwest of, 930 feet west of the west end of Micajah Tunnel of Virginian Ry., 15 feet south of railroad, 5 feet south of stone culvert, in sandstone ledge; aluminum tablet stamped "2239 1909"	2,238.689

Vivian northeast up Main Fork of Bottom Creek and down Whiteoak Branch of Pinnacle Creek to mouth.

East Vivian, 110 feet east of milepost 391, north side of railroad; chiseled square	1,510.84
Vivian, 1 mile northeast of, junction of county road and tramway up main fork of Bottom Creek, 40 feet west of stream crossing, on sandstone rock; chiseled square	1,660.75
Vivian, 3.4 miles northeast of, at south end of mound in creek bed, on sandstone bowlder; chiseled square	1,993.98
Vivian, 4.6 miles northeast of, 75 feet east of house of Thomas Inglent at foot of hill, on sandstone bowlder; chiseled square	2,153.67
Vivian, 5.5 miles northeast of, at road forks, on top of ridge, 700 feet west of house of Mr. Williams, 15 feet south of road, in sandstone ledge; aluminum tablet stamped "2432 1909"	2,432.020
Vivian, 6.7 miles northeast of, 50 feet north of road forks, in low gap, north side of county road, on sandstone ledge; chiseled square	2,289.77
Vivian, 8 miles northeast of, north side of county road down Whiteoak Branch of Pinnacle Creek, 15 feet west of small drain across road; aluminum tablet stamped "2028 1909"	2,027.943
Herndon, 7.4 miles west of, 15 feet south of county road at junction of Payne Fork with Whiteoak Branch of Pinnacle Creek, on large rock; chiseled square	1,760.91

Milepost 11 east along Norfolk & Western Ry. to Black Wolf mine.

Dearing (Black Wolf mine), 5.5 miles south of Gary, 858 feet south of milepost 12, north end of pier supporting tipple, 8 feet west of track; aluminum tablet stamped "1504"	1,504.037

Black Wolf mine east along Norfolk & Western Ry. to Anawalt (single spur line).

Gary, 6.4 miles south of, 45 feet north of milepost 13; top of south end on west side of railroad culvert marked "U.S.B.M. 1511"	1,510.63
Pageton, 465 feet north of station, in top of west side of south abutment of railroad bridge 2214 on branch line to mine; aluminum tablet stamped "1577"	1,577.244
Pageton, in front of station; top of rail	1,584.3
Pageton, 2.3 miles south of, top of south end of retaining wall at mine, 12 feet south of milepost 17, 10 feet west of track; marked square	1,679.00
Anawalt, in south end of west face of stone foundation of coal company store; aluminum tablet stamped "1716"	1,715.828

Point near Herndon southeast along highway and Virginian Ry. to Micajah tunnel.

	Feet.
Clark, 6.5 miles northwest of, on west side of county road, about 600 feet north of private road to west, in sandstone ledge; aluminum tablet stamped "2709 1909"	2,708.177
Clark, 5.5 miles northwest of, 60 feet west of crossroads, in low gap, 10 feet south of county road, on sandstone rock; chiseled square	2,416.58
Clark, 3.5 miles northwest of, 110 feet west of county road, in low gap over Micajah tunnel of Virginian Ry, on sandstone ledge; chiseled square	2,450.01

Point on State line 2 miles north of Smith Store, Va., north down South Fork of Tug River to Dearing.

Dearing, 7 miles south of, in West Virginia, 2.2 miles north of Smith's store, Va., on east side of road, 50 feet south of forks, in sandstone ledge; aluminum tablet stamped "2528 VA 1909"	2,527.635
Dearing, 5.8 miles south of, on straight bend of road to southwest, on north side of road, on sandstone rock; chiseled square	2,014.59
Dearing, 4.8 miles south of, 615 feet north of mouth of Laurel Branch, 5 feet west of road, on sandstone bowlder; chiseled square	1,717.71
Dearing, 3 miles south of, 0.8 mile northwest of Taylor's store, east side of road, 30 feet south of Jump Branch, in flat sandstone rock; aluminum tablet stamped "1620 1909"	1,619.692
Dearing, 0.7 mile south of, on west side of road, 20 feet south of stream crossing, highest point on oblong sandstone rock; marked circle	1,506.13

Bluestone southwest along Norfolk & Western Ry. branch to State line crossing (part of double line to Pocahontas, Va.).

Bluestone, in north end of east abutment of railroad bridge 851; aluminum tablet stamped "2283"	2,283.248
Virginia-West Virginia State line crossing, at road crossing, north of long tunnel; top of rail; warning post marked "U.S. 2308"	2,308.0

WELCH 15′ (TAZEWELL 30′) QUADRANGLE.

Serpell east along Norfolk & Western Ry. to East Vivian.

Serpell, in front of station; top of rail	1,062.8
Serpell, 1.3 miles east of, 400 feet east of milepost 414, in east end of culvert over running stream; aluminum tablet stamped "1077"	1,076.402
Roderfield, in front of station; top oj rail	1,094.9
Roderfield, 1.9 miles east of, 400 feet southwest of milepost 411, in south end of west abutment of new railroad bridge over Tug River; aluminum tablet stamped "1134"	1,134.062
Claren, in front of station; top of rail	1,133.8
Twin Branch, 200 feet east of mouth of tunnel, 80 feet west of station, in north end of east abutment of railroad bridge 902; aluminum tablet stamped "1178"	1,177.735
Davy, 100 feet southwest of milepost 407, south end of east bridge seat of railroad bridge 901; chiseled square	1,180.03
Davy, in front of station; top of rail	1,191.3
Davy, 1.25 miles east of, 275 feet east of mouth of tunnel, in south end of east abutment of railroad bridge 899-A; aluminum tablet stamped "1225"	1,224,509
Davy, 3.8 miles east of, on south end of bridge seat of east abutment of railroad bridge 997; chiseled square	1,263.01

	Feet.
Davy, 4.6 miles east of, 250 feet west of double tunnel, 60 feet west of milepost 401, in north end of east abutment of railroad bridge 895; aluminum tablet stamped "1281"	1,281.265
Welch, on south end of east abutment of railroad bridge 893; chiseled square	1,298.96
Welch, on west side of front entrance to First National Bank, in fourth tier of stone above foundation; aluminum tablet stamped "1304"	1,303.434
Welch, in front of station; top of rail	1,300.7
Huger, in front of station; top of rail	1,332.4
Huger, 0.7 mile east of, in northwest corner of concrete arch over wagon road; aluminum tablet stamped "1361"	1,361.293
Huger, 2.8 miles east of, 130 feet east of milepost 394, 50 feet east of Cirrus Coal & Coke Co. store, on concrete well curb; top of screw	1,446.57
West Vivian, railroad junction west of, in south end of west abutment of railroad bridge 885-A over Elkhorn Creek; aluminum tablet stamped "1476"	1,475.423

Welch, southeast along Norfolk & Western Ry. to milepost 11.

Welch, on south end of east abutment of railroad bridge 893; chiseled square marked "No. 25 U. S. B. M. 1299"	1,298.958
Welch, 3.1 miles south of, 4 feet north of milepost 3, 280 feet south of railroad bridge 2,202, on face of side corner; aluminum tablet stamped "1349"	1,349.006
Wilcoe, in front of station; top of rail	1,379.4
Kennon, opposite station platform, on east side of track, at road crossing, in top of north end of railroad culvert; aluminum tablet stamped "1395"	1,395.172
Kennon, in front of station; top of rail	1,395.8
Gary, in front of station; top of rail	1,401.1
Gary, 0.4 mile south of, 40 feet south of milepost 7, 10 feet west of track, on top of rock; square marked "U.S.B.M. 1412"	1,411.66
Gary, 2.5 miles south of, 765 feet south of milepost 9, 35 feet south of railroad crossing, 12 feet east of track, in top of large rock; aluminum tablet stamped "1454"	1,453.871

Atwell southeast up Dry Fork along Norfolk & Western Ry. to Berwind (continuance of a single spur line from Iaeger).

Atwell, 1.6 miles southeast of, 1,855 feet south of milepost 15, in west side of south abutment of railroad bridge 2277; aluminum tablet stamped "1268"	1,267.775
English, in front of station; top of rail	1,292.2
English, 0.4 mile southeast of, south of milepost 18, 20 feet west of track, on large rock used as an anchor for smoke stack guy; aluminum tablet stamped "1296"	1,296.055
English, 1.3 miles southeast of, 65 feet south of milepost 19, 20 feet east of track, on large rock; square marked "U.S.B.M. 1313"	1,312.59
English, 3.2 miles southeast of, 493 feet north of milepost 21, top of railroad culvert at south end of west abutment of; aluminum tablet stamped "1335"	1,334.308
War, in front of station; top of rail	1,341.7
English, 5.3 miles southeast of, at milepost 23, top of south abutment on west side of railroad bridge 2280; square marked "U.S.B.M. 1377"	1,377.15
English, 6.2 miles southeast of, 611 feet north of milepost 24, top of north end of west abutment of railroad culvert; aluminum tablet stamped "1403"	1,402.383

	Feet.
English, 7.9 miles southeast of, in west side of top of south abutment of railroad bridge over Jacob Fork; square marked "U.S.B.M. 1452"	1,451.32
Berwind, in front of station; top of rail	1,482.8
Berwind, 0.1 mile southeast of, 270 feet south of milepost 27, in top in center of west side of railroad culvert; aluminum tablet stamped "1487"	1,486.917

Rift, W. Va., up Jacob Fork to Big Creek, thence up Big Creek to Squirejim post office (unchecked spur line).

English, 7.9 miles southeast of; west side of south abutment of railroad bridge over Jacob Fork, top; square marked "U.S.B.M. 1452"	1,451.32
Rift, 1.1 miles east of, 200 feet northwest of forks of Big Creek and Jacob Fork of Dry Fork, 5 feet north of wooden tramway, in sandstone rock; aluminum tablet stamped "1453"	1,452.851
Rift, 2.5 miles east of, 2 feet south of tramway; chiseled square on sandstone rock marked "U. S. B. M. 1498"	1,498.50
Rift, 4 miles east of, 3 feet north of tramway; chiseled square on sandstone ledge marked "U. S. B. M. 1532"	1,532.08
Rift, 5.6 miles east of, 175 feet south of forks of Long Branch and Big Creek, 20 feet south of tramway, in sandstone rock; aluminum tablet stamped "1576"	1,576.076
Squirejim, 4 miles northwest of, 5 feet north of trail; chiseled square on sandstone rock marked "U.S.B.M. 1603"	1,603.14
Squirejim, 3 miles northwest of, 40 feet south of trail; point on top of large sandstone rock marked "U.S.B.M. 1650"	1,649.77
Squirejim, 1.7 miles northwest of, 450 feet south of house at mouth of hollow, 30 feet east of road; chiseled square on sandstone marked "U.S. B.M. 1700"	1,699.93
Squirejim, 1 mile northwest of, 80 feet south of house at stream forks, 10 feet east of road; chiseled square on sandstone rock marked "U.S.B.M. 1714"	1,714.38
Squirejim, 600 feet north of, 40 feet east of road, 125 feet west of schoolhouse, in sandstone ledge; aluminum tablet stamped "1805"	1,805.086

IAEGER QUADRANGLE (TAZEWELL 30′ QUADRANGLE).

Point 0.8 mile east of Panther south along tramway up Panther Creek to Meethouse Fork of Panther Creek.

Panther, 0.8 mile east of, in south end of east bridge seat of railroad bridge 915 over Short Pole Creek; aluminum tablet stamped "944"	943.096
Panther, in front of station; top of rail	944
Panther, 0.4 mile south of, 10 feet east of tramway; chiseled square on sandstone ledge marked "941"	941.21
Panther, 1.4 miles south of, opposite Trap Fork, 10 feet east of tramway; chiseled square on sandstone rock marked "972"	971.998
Panther, 2 miles south of, 100 feet north of junction of Trace Fork and Panther Creek, 8 feet east of iron tramway, in sandstone ledge; aluminum tablet stamped "988"	988.475
Panther, 3.9 miles south of, 5 feet west of tramway opposite small branch to left, on sandstone bowlder; chiseled square marked "1052"	1,052.02
Panther, 5.1 miles south of, 7 feet north of iron tramway, on sandstone bowlder; chiseled square marked "1097"	1,097.26
Panther, 5.9 miles south of, 70 feet northeast of junction of George Fork and Panther Creek, 25 feet east of tramway, in large sandstone rock; aluminum tablet stamped "1134"	

	Feet.
Panther, 7.4 miles south of, south end of cleared bottom, 35 feet east of tramway, on sandstone rock; chiseled square marked "1186"	1,186.02
Panther, 8.2 miles south of, in creek bed; point on top of large sandstone rock marked "1199"	1,199.36
Panther, 8.9 miles south of, 80 feet north of junction of Meethouse Fork and Panther Creek, in large sandstone rock at end of iron tramway; aluminum tablet stamped "1232"	1,232.081

Mohawk southeast and east along Norfolk & Western Ry. to Serpell.

Mohawk, 1.1 miles southeast of; point on telegraph pole marked "932.54" (railroad bench mark)	934.40
Panther, west of station, at road crossing; top of rail	944.1
Panther, 0.8 mile east of, in south end of east bridge seat of railroad bridge 915 over Short Pole Creek; aluminum tablet stamped "944"	943.096
Panther, 2.5 miles east of, 35 feet east of milepost 427, on sandstone bowlder; chiseled square	958.54
Hull, in front of station; top of rail	961.0
Hull, 350 feet east of station, 50 feet north of railroad, in west end of sandstone culvert; aluminum tablet stamped "960"	959.414
Bridge 913, north side, in east bridge seat; top of bolt (railroad bench mark)	960.86
Hull, 1.7 miles east of, 40 feet south of milepost 424, on rock; chiseled square	969.92
Iaeger, at junction of main line and Dry Fork branch of Norfolk & Western Ry., in east end of north abutment of railroad bridge over Tug River; aluminum tablet stamped "981"	980.370
Iaeger, 1 foot south of tablet; top of iron bolt (railroad bench mark)	981.44
Iaeger, in front of station; top of rail	982.1
Bridge 911, on east abutment (railroad bench mark)	984.98
Iaeger, 2.1 miles east of, north end of west abutment of railroad bridge 910; aluminum tablet stamped "996"	995.374
Iaeger, 3 miles east of, 850 feet east of milepost 419, north end of west abutment of railroad bridge 909; chiseled square	1,008.58
Wilmore, on north end of west abutment of railroad bridge 908 (railroad bench mark)	1,022.73
Wilmore, 350 feet west of telegraph office and milepost 417, 100 feet north of railroad, 10 feet north of fence corner, in sandstone bowlder; aluminum tablet stamped "1036"	1,035.942
Wilmore, in front of station; top of rail	1,038.1
Wilmore, 1 mile east of, 15 feet east of milepost 416, on east end of sandstone culvert; chiseled square	1,051.14

Iaeger southeast along Norfolk & Western Ry. up Dry Fork to Atwell (single spur line).

Iaeger, junction of main line and Dry Fork branch of Norfolk & Western Ry., in east end of north abutment of railroad bridge over Tug River; aluminum tablet	980.370
Iaeger, 3.1 miles south of, 854 feet south of milepost 3, west of track, in top of railroad culvert; aluminum tablet stamped "1024"	1,024.153
Iaeger, 4 miles south of, 20 feet south of milepost 4, 6 feet west of track, on top of large rock; square; marked "U.S.B.M.1038"	1,036.30
Ritter, in front of station; top of rail	1,043.3
Ritter, 1.2 miles south of, in top of south abutment, west end of railroad bridge 2275; aluminum tablet stamped "1061"	1,060.394

	Feet.
Ritter, 2.4 miles south of, 45 feet south of milepost 7, west of track, top of railroad culvert; square marked "U.S.B.M.1088"	1,087.54
Carlos, in front of station sign; top of rail	1,092.9
Carlos, 1.8 miles south of, 90 feet south of milepost 9, 10 feet east of track, in top of railroad culvert; aluminum tablet stamped "1132"	1,131.937
Bradshaw, in front of milepost 11; top of rail	1,179.5
Bradshaw, 0.9 mile southeast of, 534 feet north of milepost 12, 6 feet west of track, in top of railroad culvert; aluminum tablet stamped "1199"	1,198.855
Atwell, in front of station; top of rail	1,237.1

Gilbert, Holden, Logan, Louisa, Matewan, Naugatuck, and Williamson 15′ quadrangles (Kenova, Oceana, and Warfield 30′ quadrangles).

LOGAN, MINGO, WAYNE, AND WYOMING COUNTIES.

The following elevations were determined by primary leveling extended from Graham, Va., and Catlettsburg, Ky., points of the precise level net.

The leveling was done in the Gilbert quadrangle in 1896 by Hargraves Wood, and in 1909 by J. H. Wilson and T. A. Green; in the Louisa, Matewan, Naugatuck, and Williamson quadrangles in 1909 by T. A. Green; and in the Holden, Logan, and Naugatuck quadrangles in 1910 by S. E. Taylor. One bench mark in the Naugatuck quadrangle was set in 1907 by E. S. Dawson.

GILBERT 15′ (OCEANA 30′) QUADRANGLE.

Man northeast up Buffalo Creek (double spur line).

	Feet.
Man, 0.25 mile above mouth of Buffalo Creek, opposite Martin Doss' place and 60 feet above foot log, on west side of Buffalo Creek, in rock; copper bolt stamped "U. S. G. S. 728 Ft. B. M."	729.102
Buffalo Creek, 2 miles above mouth of; nail in root of sycamore tree on east side of road	785.60

Man up Rockhouse Branch (single spur line).

Man, 2 miles southwest of, 1 mile above mouth of Rockhouse Creek, west side of creek, in rock near south end of cliff; copper bolt stamped "U.S. G.S. 792 Ft. B. M."	793.331

Up Big Huff Creek from mouth to Beech Branch.

Man, 1 mile south of, east side of and 300 feet above mouth of Big Huff Creek, in rock; copper bolt stamped "U.S.G.S. 727 Ft. B. M."	728.537
Big Spring Branch, 1,800 feet above crossing of; nail in root of sycamore on north side of road	794.09
Cyclone, opposite Henchman's house, in rock; copper bolt stamped "U.S. G.S. 854 Ft. B. M."	855.492
Lem Brown's place; nail in root of poplar tree on south side of road	994.51

Point near Man south along road up Guyandot River to Gilbert.

Guyandot River, 200 feet above Wayne McDonald's store; nail in root of small sycamore tree on west side of road	760.72
Spice Creek, 0.5 mile above, 1 mile below Jim Justice's place; nail in root of white walnut tree on north side of road	771.60
Gilbert, 1 mile below, 200 feet above old mill race where wagon road crosses river; nail in root of sycamore tree with spreading roots	804.97

Gilbert south up Gilbert and down Ben Creeks to Wharncliffe.

	Feet.
Gilbert, opposite Alexander Stafford's store, in field; iron post stamped "832"	833.146
Gilbert Creek, 1 mile above mouth of, in creek and road at first crossing above Zat Ellis's house; rock marked "B. M."	848.62
Gilbert Creek, 0.5 mile above Horsepen Creek, 600 feet below Scott Bliss's; nail in root of beech tree on east side of road	892.06
Ben Creek, head of right fork below deserted cabin, on east side of road near rock cut at foot of mountain; chisel mark on rock	1,201.07
Wharncliffe, 4 miles northeast of, 300 feet below Laurel Branch, on east side of road, opposite T. E. Brown's house, Ben Creek; iron post stamped "1020"	1,021.315
Ben Creek, 200 feet above Spring Fork Branch, at Michael Hatfield's; nail in root of black oak tree on west side of road	890.82

Elevation at Wharncliffe redetermined by leveling of 1909.

Wharncliffe, 0.5 mile south of, corner of State line between Kentucky, Virginia, and West Virginia; iron post stamped "825"	826.697

Wharncliffe southeast up Big Sandy River and Long Pole Creek (single spur line).

Dotson, 4 miles east of, up Long Pole Creek, 1,200 feet below Oak Branch, on south side of road; iron post stamped "1050"	1,051.819

Along Island Creek from Little Creek to Three Forks.

Oilville, 4.4 miles southeast of, 1.8 miles south of Lewis Chafin's place, 350 feet south of coal chute, on east side of road; point on arch of triangular shaped rock marked "U. S. □ B. M. 953"	952.44
Crane's sawmill, 0.5 mile south of, 400 feet north of Anne Hatfield's house, 10 feet west of river, in arch of large sandstone bowlder; aluminum tablet stamped "1048"	1,047.776

Point near Calico east along road down Horsepen Fork to Gilbert.

Calico, 0.6 mile north of, 5 feet west of road, 400 feet north of private coal chute, in sandstone outcrop; aluminum tablet stamped "1505 W. Va. 1909"	1,504.447
Calico, at forks of road, west of post office, on west side of road, 50 feet north of forks; point on sharp projection of sandstone outcrop marked "U.S. □ B.M. 1610"	1,609.161
Calico, 1 mile east of, 25 feet south of road, 150 feet south of coal opening; copper nail in root of 1-foot beech tree marked "U.S.B.M. 1390"	1,389.52
Calico, 2 miles east of, on west side of road, on south side of creek, near telephone pole 15 feet south of road; highest point on oblong sandstone rock marked "U.S.B.M. 1198"	1,197.84
Calico, 3 miles east of, on west side of road, 300 feet west of rock wall at mouth of Coon Branch, in sandstone bowlder 3 by 3 by 3 feet; bronze tablet stamped "1108 W. Va. 1909"	1,107.310
Calico, 5.4 miles east of, at junction of Horsepen and Browning forks of Gilbert Creek, 30 feet north of front entrance to Farrell schoolhouse, 20 feet west of elm tree 3 feet in diameter, in sandstone rock; bronze tablet stamped "937 W. Va. 1909"	936.580
Horsepen, 0.8 mile east of, on north side of road, on west side of ford; highest point on sandstone bowlder 4 by 3 by 2 feet marked "U.S.B.M. 852"	851.74
Horsepen, 1.8 miles east of, on north side of road, 450 feet east of blacksmith shop; highest point on brown sandstone rock marked "U.S.B.M. 823"	822.93

Gilbert north down Guyandot River and up Elk Creek to Trace Branch.

	Feet.
Gilbert, 1.9 miles northwest of, on north side of road, on lower projection of east end of ragged sandstone outcrop; bronze tablet stamped "814 W. Va. 1909"	813.388
Gilbert, 4 miles northwest of, at point where river turns sharply to west; highest point on sandstone rock on west side of road marked "U.S.B.M. 778"	777.93
Gilbert, 5.3 miles northwest of, south side of Sylvia Branch, west side of road, at point where road turns sharply up hollow, in sandstone outcrop; bronze tablet stamped "776 W. Va. 1909"	775.407
Christian, forks of road at mouth of Elk Creek, 75 feet south of Elk Creek, 60 feet north of Vance's store; copper nail in root on west side of holly tree 1 foot in diameter marked "U.S.B.M. 763"	763.02
Christian, 0.6 mile northeast of, on north side of second stream crossing above schoolhouse, in sandstone ledge; bronze tablet stamped "780 W. Va. 1909"	780.015
Christian, 3.6 miles northeast of, 8 feet north of road, 400 feet east of Ike Vance's place, in sandstone rock; bronze tablet stamped "1002 W. Va. 1909"	1,002.135
Christian, 5.7 miles northeast of, on north side of road, 200 feet east of hollow from north, 50 feet west of bars across road; point on sandstone rock marked "U.S.B.M. 1232"	1,231.95
Christian, 6.5 miles northeast of, north side of trail, west side of stream crossing, 200 feet west of old rock chimney, in sandstone ledge; bronze tablet stamped "1333 W. Va. 1909"	1,333.047

Gilbert southeast along road up Guyandot River and Left Fork to Indian Ridge.

Gilbert, 2.8 miles southeast of, on sandstone ledge on left side of road, 790 feet above mouth of branch; bronze tablet stamped "912"	912.016
Justice, 2.3 miles above, in sandstone rock on right side of road, 170 feet south of forks of road from Little Cub Creek, and 1,250 feet north of mouth of Lizard Branch; aluminum tablet stamped "1070"	1,070.342
Hanover, 150 feet south of post office, in sandstone rock on left side of road; bronze tablet stamped "1057"	1,055.987
Hanover, 2.1 miles south of, 25 feet from road on right-hand side of road up Muzzle Fork and 0.3 mile from mouth; copper nail in root of beech tree	1,094.35
Hanover, 3.3 miles south of, at foot of pine tree with big rock embedded in roots, 1,250 feet above schoolhouse, in rock on left side of road; bronze tablet stamped "1187"	1,186.939
Iaeger, 4.5 miles northwest of, 500 feet south of where road crosses Indian Ridge, on left side of road, in sandstone rock; bronze tablet stamped "1582"	1,582.009

Wharncliffe southeast along Norfolk & Western Ry. to Mohawk.

Wharncliffe, railroad bridge over Ben Creek; bridge seat of east abutment (railroad bench mark—railroad elevation 820.39 feet)	823.52
War Eagle, south end east abutment of railroad bridge over Turkey Creek; aluminum tablet stamped "875"	874.210
Alnwick, in front of station; top of rail	894.2
Wyoming, in front of station; top of rail	929.0
Wyoming, 0.2 mile east of, 110 feet east of milepost 432, in northeast corner of railroad culvert; aluminium tablet stamped "927"	926.448

Wharncliffe west along Norfolk & Western Ry. to Glenalum.

	Feet.
Wharncliffe, 1.1 miles west of, railroad bridge 920; south end of bridge seat of east abutment	816.12
Glenalum, in front of station; top of rail	810.1
Glenalum, 240 feet west of station, railroad bridge 921; north end of west abutment	807.24

MATEWAN 15′ (WARFIELD 30′) QUADRANGLE.

Sycamore northeast along road via Ragland and Oilville to Island Creek.

Merrimac, west of, 50 feet north of railroad, on north side of wagon road, in sandstone ledge; aluminum tablet stamped "677 1909"	676.701
Sycamore, 3 miles north of, summit at head of Lick Creek, on west side of road, 40 feet south of divide, in sandstone ledge; aluminum tablet stamped "1436 W. Va. 1909"	1,435.253
Sycamore, 3.9 miles north of, on west side of road, 150 feet north of stream crossing, 12 feet southwest of telephone pole marked "U.S.B.M. 867," on sandstone rock; chiseled square	866.54
Rockhouse, at junction of Pigeon and Rockhouse creeks, 50 feet northwest of footbridge over Pigeon Creek, in sandstone ledge; aluminum tablet stamped "740 1909"	739.527
Rockhouse, 1.9 miles east of, on north side of creek, 200 feet west of schoolhouse at hollow; point on sandstone outcrop marked "U.S.B.M. 807"	806.96
Ragland post office, north side of road, 50 feet east of grist mill, 75 feet northwest of Lewis Varney's house; highest point on flat sandstone bowlder 1 by 3 by 4 feet marked "U.S.B.M. 854"	853.42
Ragland, 0.2 mile east of, on south side of wagon road, 20 feet north of creek, 100 feet east of road, running north to Elk Creek, in sandstone bowlder; aluminum tablet stamped "860 W. Va. 1909"	859.761
Ragland, 1.8 miles east of, 300 feet west of Christopher Chofin's, on south side of road; point on south end of large sandstone bowlder 4 by 7 by 5 feet marked "U.S.B.M. 950"	949.68
Ragland, 3.1 miles east of, 75 feet south of road, on south side of creek, 50 feet east of hollow leading south at Harley Curry's place, in large flat sandstone rock; aluminum tablet stamped "1025 W. Va. 1909"	1,024.385
Ragland, 5.1 miles northeast of, at divide at head of Cow Creek (Mingo-Logan County line); point on west end of sandstone outcrop running directly across divide marked "U.S.B.M. 1709"	1,708.72
Ragland, 6.1 miles northeast of, south side of road, 300 feet east of Victor Curry's house, in large sandstone bowlder; aluminum tablet stamped "1384 W. Va. 1909"	1,383.530
Ragland, 8.4 miles northeast of, north side of road, south side of creek, at east end of old log, 50 feet west of footbridge; highest point on triangular sandstone rock marked "U.S.B.M. 1067"	1,066.83
Oilville, 0.3 mile east of, on south side of road, 5 feet north of fence, 150 feet west of Dave Robertson's house, in sandstone rock; aluminum tablet stamped "947 W. Va. 1909"	946.830
Oilville, 2 miles east of, at forks of road at junction of Cow and Island Creeks; point on northwest corner of stone property line post; marked "U.S.B.M. 840"	840.02
Oilville, 2.5 miles east of, 0.5 mile south of junction of Cow and Island creeks, on east side of road, 350 feet north of Lewis Chofin's house, in large sandstone bowlder; aluminum tablet stamped "859 W. Va. 1909"	858.431

Three Forks south up Island Creek to point near Calico.

	Feet.
Crane's sawmill, 3.2 miles south of, west side of road, point on flat sandstone rock on edge of stream marked "U.S.B.M. 1331"	1,330.46

Calico along highway west down Pigeon Creek to Mary Taylor's house, thence southwest to Matewan.

Calico, 0.8 mile west of, at forks of road, 12 feet south of dead beech tree just east of forks; highest point on sandstone rock marked "U.S. □ B.M. 1420"	1,419.42
Calico, 2 miles southwest of, 150 feet east of old church, 50 feet south of road, on south side of creek, in sandstone outcrop; aluminum tablet stamped "1269 W. Va. 1909"	1,268.818
Calico, 4.8 miles southwest of, 40 feet south of road, 50 feet east of small stream running south, in sandstone rock; aluminum tablet stamped "1119 W. Va. 1909"	1,118.204
Calico, 7 miles southwest of, on south side of road, 900 feet west of Fulton Hatfield's house; highest point on sharp sandstone rock marked "U.S. B.M. 1007"	1,006.09
Varney, 0.9 mile west of, on south side of road, 75 feet west of sandstone bowlder 6 by 6 by 7 feet, in south end of sandstone outcrop crossing road; aluminum tablet stamped "959 W. Va. 1909"	958.242
Varney, 3.8 miles west of, 5 feet south of road, on north side of creek, 400 feet east of road running southwest to Matewan at Mary Taylor's house, in sandstone rock; aluminum tablet stamped "860 W. Va. 1909"	859.066
Red Jacket, northeast corner of pumping station at mine, on north face; aluminum tablet stamped "739 W. Va. 1909"	738.995

Devon north up Beech Creek and over divide to point near Calico.

Devon, 0.7 mile west of, in north end of west abutment of railroad bridge No. 924 over Beech Creek; aluminum tablet stamped "753 1909"	752.991
Walker's mill, 2.5 miles northeast of, 115 feet north of mouth of Grapevine Fork, on east side of road, 60 feet northeast of store kept by Smith Hatfield, in sandstone rock; bronze tablet stamped "904 W. Va. 1909"	903.925
Hinch, 250 feet east of Bill Kenneda's house, on east side of road, 350 feet west of forks of road, in sandstone rock, 30 feet north of elm tree 36 inches in diameter; bronze tablet stamped "1212 W. Va. 1909"	1,211.566
Hinch, 1.1 miles northeast of, on east side of road, at northeast corner of fence around garden; highest point on sandstone rock 2 by 2 by 2 feet, marked "U.S.B.M. 1505"	1,504.22
Hinch, 2.9 miles northeast of, 30 feet east of road, on east side of creek, in sandstone outcrop; bronze tablet stamped "1496 W. Va. 1909"	1,495.435
Hinch, 3.5 miles northeast of, at forks of road, 0.8 mile west of Calico, at Rice Browning's place, 10 feet south of dead beech tree; point on sandstone rock marked "U.S.B.M. 1420"	1,419.424

Glenalum northwest along Norfolk & Western Ry. to East Williamson.

Glenalum, 2 miles west of, in north end of bridge seat of west abutment of railroad bridge 922; aluminum tablet stamped "790"	789.298
Lindsey, in front of station; top of rail	783.8
Lindsey, 0.2 mile west of, 240 feet west of milepost 443, on north end of east abutment of railroad bridge 923; chiseled square marked "U.S.B.M. 779"	779.11

	Feet.
Lindsey, 1.4 miles west of, 730 feet west of milepost 444, on north side of railroad, in sandstone ledge; aluminum tablet stamped "778"	777.890
Lindsey, 3.2 miles west of, 75 feet east of milepost 446, on sandstone ledge; chiseled square marked "U.S.B.M. 760"	759.38
Devon, 0.7 mile west of, in north end of west abutment of railroad bridge 924; aluminum tablet stamped "753"	752.991
Devon, 1.6 miles west of, on sandstone ledge (railroad bench mark)	751.50
Cedar, in front of station; top of rail; mail crane marked "U.S. 746"	745.2
Cedar, 0.4 mile west of, at railroad junction, in northeast corner of north abutment of railroad bridge 2,141 over Tug River; aluminum tablet stamped "743"	743.110
Vulcan, 1.1 miles west of, at Freeborn's station, in north end of east abutment of railroad bridge over Tug River; aluminum tablet stamped "727"	726.850
Delorme, in front of station; top of rail	726.5
Delorme, 0.2 mile west of, at milepost 454, in top of center rack for extra rail; nail marked "U.S.B.M.726" (railroad bench mark)	725.60
Thacker, in front of station; top of rail	715.3
Thacker, 644 feet northwest of station, in north end of west abutment of railroad bridge 927; aluminum tablet stamped "712"	711.795
Thacker, 3.4 miles northwest of, in west end of bridge seat of, north abutment of Pike Collier electric railroad bridge over Tug River; aluminum tablet stamped "701"	700.392
Northwest corner of same abutment (railroad bench mark)	701.28
Matewan, north end of east abutment of railroad bridge 928; chisel mark (railroad bench mark)	696.16
Matewan, in front of station; top of rail	697.8
State line, West Virginia-Kentucky, in center of railroad bridge 929 over Tug River; top of rail	695.22
Matewan, 1.4 miles nortwhest of north end of west abutment of railroad bridge 929 over Tug River, Kentucky side of bridge, 100 feet east of Hatfield tunnel; chiseled square marked "U.S.B.M. 693"	692.78
Matewan, 1.6 miles northwest of, in north end of west abutment of railroad bridge 930, State line bridge over Tug River; aluminum tablet stamped "691"	690.337
Merrimac, in front of station; top of rail	680.6
Merrimac, 0.2 mile northwest of, at coal tipple, in southwest foundation for water tank; aluminum tablet stamped "680"	679.959
Merrimac, 1.3 miles northwest of, 75 feet south of milepost 466, on sandstone bowlder; chiseled square	674.18
Merrimac, 2.2 miles northwest of, 300 feet east of milepost 467, 75 feet north of railroad, on north side of county road, in sandstone ledge; aluminum tablet stamped "677"	676.701

WILLIAMSON QUADRANGLE.

Williamson northwest along Norfolk & Western Ry. to Nolan.

Williamson, 200 feet east of station, at southwest corner of guardrail over subway, on sandstane coping; chiseled square marked "665"	664.27
Williamson, at southwest corner of intersection of Fifth Avenue and Harvey Street, in top of stone post; bronze meridian tablet stamped "675"	674.682
Williamson, at courthouse; U. S. Army engineers' bench mark No. 30 (Army engineers' elevation 660.774)	660.376
Williamson, 2.2 miles northwest of, 826 feet west of tunnel, on north side of railroad, on east side of county road crossing, east end of culvert; chiseled square marked "657"	656.24

	Feet.
Chattaroy, 400 feet east of station, 35 feet east of milepost 474, on north side of railroad, in sandstone ledge; aluminum tablet stamped "654"....	653.868
Chattaroy, in front of station; top of rail................................	654.9
Hatfield, in front of station; top of rail................................	652.0
Hatfield, 0.8 mile northwest of, 500 feet east of milepost 477, 60 feet north of railroad, east side of county road, in sandstone ledge; aluminum tablet stamped "650"................................	649.915
Nolan, 75 feet north of station, on sandstone bowlder; chiseled square......	647.97

NAUGATUCK QUADRANGLE.

Nolan northwest along Norfolk & Western Ry. to Yorkville.

Nolan, 2.3 miles northwest of, 130 feet northwest of road crossing, 100 feet west of milepost 480, 70 feet north of deserted house, in sandstone bowlder 15 by 108 by 10 feet; aluminum tablet stamped "645"..................	644.777
Naugatuck, at east end of siding, 25 feet south of railroad, 100 feet west of old road crossing, in sandstone culvert; aluminum tablet stamped "638".	637.728
Naugatuck, 0.9 mile northwest of, 10 feet south of road crossing, on sandstone rock; chiseled square; warning post marked "U.S.B.M. 635"......	634.52
Naugatuck, 1.9 miles northwest of, 200 feet north of railroad crossing, 75 feet west of wagon road, in sandstone rock; aluminum tablet stamped "639"................................	638.508
Naugatuck, 3.4 miles northwest of, 60 feet east of tunnel, on south side of tracks, on sandstone rock; chiseled square................................	629.98
Kermit, at road crossing, at milepost east of, on north side of railroad, on west side of wagon road, on sandstone rock; chiseled square marked "628"	628.03
Kermit, 600 feet east of station, on west side of sandstone culvert, in third tier of stone below top; aluminum tablet stamped "623"..............	622.640
Kermit, in front of station; top of rail................................	627.8
Kermit, 2.5 miles northwest of, 100 feet north of railroad, 300 feet northeast of railroad crossing, 50 feet north of wagon road, 5 feet south of gate, in sandstone rock; aluminum tablet stamped "621".....................	620.505
Crum, 0.3 mile east of, 50 feet north of railroad, on south side of county road, 100 feet northwest of milepost "Naug. 11," in sandstone bowlder; aluminum tablet stamped "619"................................	618.902
Crum, 1.95 miles northwest of, 750 feet west of mouth of tunnel, on north end of west abutment of railroad bridge 755 over Bull Creek; chiseled square marked "611"................................	610.97
Jennie, 10 feet south of northwest entrance to railroad tunnel, 150 feet east of road crossing; aluminum tablet stamped "615".....................	614.526
Millet, 1.6 miles northwest of, in east end of north abutment of railroad bridge 756 over Camp Creek; aluminum tablet stamped "603".........	602.200
Webb, in front of station; top of rail................................	600.5
Webb, 1.8 miles northwest of, 105 feet north of milepost "Naug. 20," on north side of wagon road, on east side of Coon Hollow, in sandstone rock; aluminum tablet stamped "594"................................	594.105

Near Preston.

Preston, 0.6 mile east of, 800 feet east of Wells Branch station, in northwest abutment of bridge 975 over Missouri Branch mouth; aluminum tablet stamped "704"................................	704.665

ugatuck north along old line of Norfolk & Western Ry. to point 0.8 mile north of Canterbury.

	Feet.
Naugatuck, 230 feet north of station, on northeast foundation for east water tank; chiseled square marked "636"	635.66
Blocton, in front of station; top of rail	633.8
Blocton, 0.3 mile east of, 110 feet east of road crossing, 8 feet south of railroad track; chiseled square on large sandstone rock marked "U.S.B.M. 637"	636.65
Blocton, 1.7 miles east of, 10 feet north of railroad; chiseled square on sandstone ledge marked "640"	639.98
Blocton, 2.4 miles east of, 1,150 feet west of Eugene post office, 35 feet south of road crossing, in sandstone rock; aluminum tablet stamped "634"	633.900
Eugene, in front of station; top of rail	638.8
Lenore, in front of station; top of rail	641
Lenore, 1 mile northeast of, 12 feet west of railroad track; chiseled square on sandstone rock in small hollow to west	643.33
Rapp, in front of station; top of rail	646
Lenore, 2.6 miles northeast of; top of east end of north abutment of railroad bridge 939	666.93
Lenore, 3 miles north of, in east bridge seat of north abutment of railroad bridge 941; aluminum tablet stamped "672"	672.066
Canterbury, at water tank; top of rail	686
Canterbury, 0.8 mile north of, railroad bridge 942 over Tom Run; west end of north abutment	699.20

Point 2.2 miles south of Breading northwest along Norfolk & Western Ry. to Preston.

Kirk, in front of station; top of rail	873
Buttercup, in front of station; top of rail	867
Breeden, 2.2 miles southeast of; top of east end of south abutment of railroad bridge 951	856.61
Breeden, 1.1 miles southeast of, 5 feet west of railroad track, in cut on standstone rock; chiseled square	837.85
Breeden, 800 feet east of, in top of south end of east abutment of railroad bridge 956; aluminum tablet stamped "818"	818.378
Breeden, in front of station; top of rail	816
Wilsondale, 3.3 miles southeast of, on south end of east abutment of railroad bridge 960, at branch to north; chiseled square	798.36
Wilsondale, 2.7 miles southeast of, on south end of east abutment of railroad bridge 964 over Poor Branch; chiseled square	786.42
Mingo-Wayne County line; top of rail; marked "780"	780
Wilsondale, 1.8 miles southeast of, 8 feet north of railroad and 740 feet west of Mingo and Wayne County line, in sandstone ledge; aluminum tablet stamped "781"	780.979
Wilsondale, 300 feet west of, 10 feet north of railroad track; chiseled square on standstone rock	761.34
Doane, 3 miles southeast of, in top of west bridge seat of south abutment of railroad bridge 967 over Gourd Branch; aluminum tablet stamped "746".	745.901
Doane, 2.6 miles southeast of, 30 feet south of railroad track, 100 feet west of milepost "N 514;" chiseled square on sandstone rock	718.78
Doane, 1.4 miles southeast of, on west end of railroad bridge 971 over Twelvepole Creek; chiseled square	738.76
Doane, 0.4 mile east of, 10 feet north of railroad track, in sandstone rock; aluminum tablet stamped "722"	722.375

	Feet.
Doane, in front of station; top of rail	721
Wells Branch, 2 miles southeast of, on east side of north abutment of railroad bridge 974 over Arkansas Branch; chiseled square	717.87
Wells Branch, 1.1 miles southeast of, 10 feet north of railroad track; chiseled square on sandstone ledge	711.64
Preston, 0.6 mile east of, 800 feet east of Wells Branch station, in northwest abutment of bridge 975 over mouth of Missouri Branch; aluminum tablet stamped "704"	704.665

Lenore station east along country road up Pigeon Creek 3 miles.

Lenore, 115 feet north of station; chiseled square on sandstone ledge	650.08
Lenore, 1.6 miles east of, 100 feet southeast of dwelling house, 6 feet south of center of road; chiseled square on sandstone rock	637.26
Lenore, 2 miles east of, 5 feet south of county road; chiseled square on sandstone rock	655.67
Lenore, 3 miles east of, 5 feet north of county road; chiseled square on sandstone ledge	653.03

HOLDEN QUADRANGLE.

Point 2.2 miles north of Canterbury north along old line of Norfolk & Western Ry. to point 0.2 mile east of Kirk.

Canterbury, 2.2 miles north of, 580 feet east of mouth of hollow from north, 5 feet north of railroad track; chiseled square on sandstone ledge	775.08
Canterbury, 3.1 miles north of, 5 feet north of railroad track, 250 feet west of hollow to north, in sandstone rock; aluminum tablet stamped "818".	818.136
Canterbury, 4 miles northeast of, 100 feet east of large hollow to north, 8 feet south of railroad track; chiseled square on sandstone ledge	865.97
Hale, at southwest corner of station, top of sandstone	909.48
Dingess, 1.4 miles south of, 8 feet west of railroad, in sandstone ledge; aluminum tablet stamped "949"	949.053
Dingess, 115 feet east of station, east side of wagon road; chiseled square on sandstone ledge	1,007.02
Kirk, 3.4 miles southeast of, 8 feet south of railroad, 200 feet south of junction of Dingess Trace and Twelvepole Creek; bronze tablet stamped "944"	944.405
Kirk, 3.4 miles southeast of, 8 feet south of railroad track; chiseled square on sandstone rock	943.91
Kirk, 2.4 miles southeast of, chiseled square on top of north end of west abutment of railroad bridge	908.45
Kirk, 1.4 miles east of; chiseled square on north end of east abutment of railroad bridge 945	894.21
Kirk, 0.2 mile east of, in top of north bridge seat of east abutment of railroad bridge 948; aluminum tablet stamped "873"	873.010

Point 3.4 miles southeast of Kirk at forks of Dingess Trace and Twelvepole Creek up Dingess Trace over country road northwest to Chapmanville, thence southeast to point 2.2 miles south of Chapmanville, thence to point 1 mile west of Logan, thence to point 4 miles east of Lenore.

Kirk, 3.4 miles southeast of, 200 feet south of Dingess Trace and Twelvepole Creek, 8 feet south of railroad, in sandstone rock; bronze tablet stamped "944"	944.405
Dingess, 3.1 miles north of, on south side of road, 100 feet east of dwelling house; chiseled square on sandstone ledge	1,075.34

	Feet.
Dingess, 4.1 miles north of, 5 feet west of county road; chiseled square on sandstone ledge	1,209.49
Dingess, 5.1 miles north of, 16 feet east of center of wagon road, 1,400 feet south of Coon Branch, in sandstone ledge; aluminum tablet stamped "956"	955.827
Whirlwind, 2 miles southwest of, on south side of road; chiseled square on sandstone ledge	967.38
Whirlwind, 0.25 mile north of, 150 feet north of road forks at junction of Bull Work and Big Hart Creeks, 20 feet east of road in creek bed, in sandstone ledge; aluminum tablet stamped "723"	723.042
Whirlwind, 1.3 miles north of; top of sandstone rock at hollow to left of road	681.65
Whirlwind, 2 miles north of, 1,000 feet south of Hoover Fork of Big Hart Creek, east side of road and east side of creek; chiseled square on sandstone ledge	666.04
Whirlwind, 3.1 miles north of, 200 feet south of forks of Buck Fork and Big Hart Creek, east side of creek; aluminum tablet stamped "648"	647.805
Junction of Smokehouse Fork and Big Hart Creek, 1.2 miles east of, on west side of creek bed, 3 feet above surface of water; chiseled square on sandstone rock	652.58
Junction of Smokehouse Fork and Big Hart Creek, 2.2 miles east of, in sandstone ledge, north side of county road, 200 feet northwest of house and store; aluminum tablet stamped "682"	682.526
Junction of Smokehouse Fork and Big Hart Creek, 3.4 miles east of; chiseled square on sandstone rock north side of wagon road	700.10
Shively, 1.8 miles north of, 50 feet west of road forks at junction of Trace and Smokehouse forks, 13 feet inside fence around small bottom, in sandstone rock; aluminum tablet stamped "758"	758.112
Shively, 2.5 miles north of, on south side of road, 50 feet west of divide between Smokehouse Fork and Crawley Creek; chiseled square on sandstone rock	984.20
Shively, 2.8 miles north of, 5 feet north of county road; chiseled square on sandstone rock	857.04
Shively post office, 3.8 miles north of, 20 feet west of center of road; chiseled square on sandstone rock	648.08
Forks of Pitt Branch and Crawley Creek, 180 feet east of, 25 feet south of wagon road, in large sandstone rock; bronze tablet stamped "635"	635.149
Chapmanville, 3 miles west of, 500 feet north of Striker Fork; chiseled square on sandstone rock 10 feet east of road	622.63
Chapmanville, 1.3 miles west of, 12 feet north of railroad track; chiseled square on sandstone rock	641.83
Chapmanville, in south side of southeast concrete pillar for railroad station platform; bronze tablet stamped "647"	646.895
Chapmanville, 2.1 miles south of, 35 feet north of railroad crossing, 5 feet west of railroad track; chiseled square on sandstone rock	652.52
Chapmanville, 2.8 miles south of, 600 feet west of Godby crossing, 8 feet north of railroad track, in sandstone ledge; bronze tablet stamped "655".	653.908
Logan, 1 mile west of, on south side of east abutment of railroad bridge over Island Creek, 200 feet north of forks of Island Creek and Copperas Mine Fork; chiseled square	666.62
Logan, 2 miles southwest of, 8 feet south of railroad track; top of standstone rock	676.50
Logan, 2.8 miles southwest of, 300 feet northwest of mouth of Whitman Fork, in south bridge seat of west abutment of railroad bridge over Copperas Mine Fork of Island Creek; bronze tablet stamped "690"	689.467

	Feet.
Holden, 300 feet east of station, north end of west abutment of wagon bridge over Truce Fork at mouth; chiseled square marked "735"	733.73
Holden, 1 mile southwest of, on west side of stream, 350 feet north of hollow to right of road; chiseled square on sandstone ledge	802.27
Holden, 1.6 miles southwest of, on north side of stream, 250 feet north of hollow to left of road; chiseled square on sandstone ledge	850.87
Holden, 1.9 miles southwest of, on north side of road, 100 feet north of stream forks to north, 150 feet east of house, in sandstone rock; bronze tablet stamped "885"	883.710
Holden, 2.7 miles southwest of, 200 feet west of stream forks, at foot of hill; point on sandstone rock	1,021.27
Holden, 3.5 miles southwest of, 90 feet west of divide between Trace Fork of Island Creek and Trace Fork of Pigeon Creek; chiseled square on sandstone rock	1,401.89
Holden, 4.5 miles southwest of, 7 feet north of center of wagon road, 200 feet west of hollow to right, in sandstone ledge; bronze tablet stamped "1033"	1,031.627
Holden, 5.9 miles southwest of, 250 feet southeast of schoolhouse, 35 feet south of road; chiseled square on sandstone rock	877.60
Holden, 7.7 miles southwest of, 90 feet south of road, 300 feet west of old splash dam; chiseled square on sandstone rock	787.13
Holden, 8.2 miles southwest of, 1,700 feet southeast of house at hollow to right, in sandstone ledge 20 feet east of creek bed and on east side of road; bronze tablet; stamped "762"	760.873
Myrtle, 1.5 miles north of, 300 feet west of large hollow to right, on sandstone rock on north side of creek	722.41
Myrtle, 0.8 mile west of, on north side of creek, between creek and road; chiseled square on sandstone rock	690.91
Myrtle, 2.3 miles west of, on south side of creek and just opposite hollow to right of road; chiseled square on sandstone rock	662.52
Forks of Trace Fork and Pigeon Creek, 4 miles east of Lenore, on north side of county road, in sandstone ledge; aluminum tablet stamped "645"	645.071
Lenore, 4 miles east of, 80 feet east of forks of Trace Fork and Pigeon Creek, on north side of county road, in sandstone ledge; aluminum tablet stamped "645"	645.071

LOGAN QUADRANGLE.

Point 0.4 mile north of Pecks Mill south along railroad to Logan.

Pecks Mill, 0.4 mile north of, 10 feet east of railroad track; chiseled square on sandstone ledge	661.12
Pecks Mill, in front of station, top of rail	660
Pecks Mill, 1 mile south of, 10 feet east of railroad track; chiseled square on sandstone ledge	661.20
Ralumco, in front of station; top of rail	661
Pecks Mill, 2.1 miles south of, 700 feet south of Ralumco station, 10 feet east of railroad track, in sandstone ledge; bronze tablet stamped "662"	660.809
Henlawsen, in front of station; top of rail	667
Henlawsen, 0.6 mile south of, 10 feet east of railroad track; chiseled square on sandstone rock	666.91
Peach Creek, in front of station; top of rail	663.7
Peach Creek station, 0.4 mile south of, railroad bridge over stream to east; northeast corner of south abutment	668.46
Logan, in front of station; top of rail	674.8
Logan, in south side of west entrance to courthouse; bronze tablet stamped "683"	681.656
Logan, stone step of Gyan Drug Co.'s building, marked "680"	679.120

LOUISA QUADRANGLE.

Yorkville northwest along Norfolk & Western Ry. to Louisa, Ky.

	Feet.
Yorkville, 600 feet east of post office, in east end of south abutment of railroad bridge 758 over Lost Creek; aluminum tablet stamped "589"	588.857
Glenhayes, in front of station; top of rail	590.8
Glenhayes, 1.2 miles northwest of, 150 feet east of milepost "Naug. 26," on west end of sandstone culvert; chiseled square marked "588"	587.27
Glenhayes, 2.25 miles northwest of, 50 feet north of milepost "Naug. 27," in sandstone bowlder; aluminum tablet stamped "595"	594.265
Saltpeter, in front of station; top of rail	582.4
Saltpeter, 200 feet northwest of station, 75 feet north of railroad, on south side of wagon road, in sandstone bowlder 20 by 15 by 8 feet; aluminum tablet stamped "574"	574.044
Saltpeter, 1.9 miles northwest of, 250 feet north of railroad, 500 feet northeast of milepost "Naug. 32," in Jerry Bartram's field, in sandstone rock; aluminum tablet stamped "579"	578.324
Saltpeter, 3.2 miles northwest of, on north end of west abutment of railroad bridge 759; chiseled square	575.32
Fort Gay, on west end of north abutment of toll bridge over Big Sandy River; chiseled square	576.19
Louisa, Ky., at lock No. 3 (United States Army Engineer's bench mark No. 13, Engineers' elevation, 569.570 feet)	569.172

Bald Knob, Mullens, and Pineville quadrangles.

BOONE, LOGAN, RALEIGH, AND WYOMING COUNTIES.

The elevations in the following list are based upon the 1903 adjustment by the Coast and Geodetic Survey and are in accord with the values given in Bulletin 399.

Most of the leveling was done in 1910 by J. B. Metcalfe, jr., but that in the south part of the Mullens quadrangle was done in 1909 by S. E. Taylor, and that in the northwest corner of the Pineville quadrangle in 1896–7 by Hargraves Wood.

PINEVILLE QUADRANGLE.

Davy (Hallsville post office) north along public roads to Oceana.

	Feet.
Davy, 0.8 mile east of, 100 feet southeast of milepost 406; chiseled square on rock	1,213.870
Davy, 100 feet southwest of milepost 407, on south end of east bridge seat of railroad bridge 901; chiseled square	1,180.03
Davy, 2.7 miles north of, 2 feet west of road and about 250 feet south of top of gap; oval chiseled on rock	1,783.85
Davy, 2.7 miles north of, 4 feet east of road and about 3 feet below it, 250 feet south of gap in mountain, in rock; aluminum tablet stamped "1777"	1,776.880
Davy, 4.9 miles north of, about 200 feet west of schoolhouse and 20 feet southeast of old cabin, 3 feet east of road; cross on rock	1,393.63
Davy, 5.9 miles north of, 3 feet north of road, 500 feet west of old splash dam; cross on top of rock	1,334.11
Brier, 150 feet north of post office, east side of road; cross on rock	1,251.56
Brier, 150 feet north of post office, 10 feet east of road, about 4 feet above level of same, in ledge of rock; aluminum tablet stamped "1255"	1,255.469
Indian and Brier creeks, surface of water at junction of; May, 1910	1,205
Indian and Brier creeks, 50 feet northeast of junction of, on south side of road, in root of red oak tree; nail	1,214.97

	Feet.
Davy, 7.8 miles north of, 250 feet west of point where drain crosses road, 4 feet north of road; chiseled oval on rock	1,226.40
Davy, 8.8 miles north of, about 800 feet northeast of Indian Creek crossing, 200 feet southwest of hilltop, north side of road; cross on rock	1,193.69
Baileysville, 0.3 mile north of, 6 feet west of road, at mouth of small drain, in ledge of rock; aluminum tablet stamped "1139"	1,138.714
Baileysville, 1 mile north of, south side of road, in top of gap; cross on rock	1,442.68
Baileysville, 2 miles north of, 40 feet north of schoolhouse, 50 feet south of road forks and creek crossing; cross on rock	1,254.54
Baileysville, 2.9 miles north of, 100 feet north of sharp turn in road where trail leaves road to left and goes up Clear Fork, 6 feet east of road, in ledge of rock; aluminum tablet stamped "1205"	1,204.692
Baileysville, 4.8 miles north of, in front of H. W. Sanders's residence, 3 feet west of road, 4 feet north of gate to yard; cross on second stone step marked "1211.5"	1,211.65
Baileysville, 6.4 miles north of, about 12 feet below level of road, 30 feet west of road, 10 feet south of large white oak tree, about 700 feet south of where road comes back on Clear Fork, in rock; aluminum tablet stamped "1221.5"	1,221.711
Baileysville, 7.1 miles north of, 150 feet north of where road crosses Clear Fork on east bank of creek, 150 feet southwest of house; cross on corner stone	1,228.92
Oceana, 400 feet east of post office, 50 feet south of Oceana high school building, south side of southwest corner of office of school building, north side of street, about 3.5 feet above level of ground, in brick wall; aluminum tablet stamped "1259"	1,259.218

Oceana east and south along roads to Pineville.

Oceana, 1.2 miles east of, at junction of Laurel and Clear Fork creeks, 20 feet south of store, in forks of road; cross on rock	1,261.56
Oceana, 3.5 miles east of, 6 feet west of road, between road and Laurel Fork, about 250 feet west of G. E. Walker's house; cross on rock	1,329.39
Oceana, 3.5 miles east of, 6 feet west of road and between same and Laurel Fork, about 250 feet west of G. E. Walker's house, in rock; aluminum tablet stamped "1331"	1,331.166
Oceana, 5.6 miles southeast of, 4 feet west of road, about 300 feet north of house on opposite side of Laurel Fork; nail in root of beech tree	1,357.77
Oceana, 5.6 miles southeast of, about 300 feet north of house, in bend of Laurel Fork, on opposite side of creek, about 12 feet above level of road, in rock; aluminum tablet stamped "1363"	1,363.168
Jesse, 15 feet north of post office, in southwest corner of road; nail in root of walnut tree (railroad bench mark)	1,365.55
Jesse, 2 miles southeast of, 100 feet south of where road crosses Elkins Fork, about 0.5 mile from top of Elkins Gap, southeast of road; nail in root of white oak stump	1,767.28
Jesse, 3.6 miles southeast of, 6 feet south of forks to southwest, at foot of mail-box; cross on rock	1,711.26
Rockview, 100 feet northwest of post office, 8 feet west of road and about 5 feet above it, in rock; aluminum tablet stamped "1628"	1,627.919
Jesse, 6.8 miles southeast of, 15 feet northwest of ford over Rock Castle Creek, 25 feet southeast of old log building; cross on sharp pointed rock	1,378.42
Pineville, 250 feet northeast of schoolhouse building, between two roads that fork at schoolhouse, in rock; aluminum tablet stamped "1323"	1,323.727

Baileysville northeast along public roads to point 2.5 miles south of Pineville.

	Feet.
Brier Creek, 1.3 miles southeast of, south side of road, about 500 feet east of prominent bend in road to left; nail in root of large sycamore tree......	1, 217. 03
Brier Creek, 2.6 miles east of, south side of road and 6 feet east of drain; cross on rock......	1, 224. 36
Brier Creek, 2.6 miles east of, 50 feet northeast of road, about same distance east of drain, in ledge of rock; aluminum tablet stamped "1236"......	1, 236. 080
Brier Creek, 3.4 miles southeast of, south side of road and 30 feet west of where Dry Branch crosses road; cross on rock......	1, 241. 22
Mulberry, 600 feet east of post office, 30 feet south of schoolhouse and 20 feet south of road, 10 feet north of branch; cross on rock......	1, 276. 49
Mulberry, 600 feet east of post office, 60 feet north of road, about 50 feet northwest of schoolhouse, in ledge of rock; aluminum tablet stamped "1282"......	1, 282. 149
Mulberry, 2 miles east of, south side of road, about 1 mile from top of gap, west side of gap; cross on ledge of rock......	1, 548. 64
Mulberry, 3 miles east of, 140 feet east of gap, south side of road; cross on rock......	1, 805. 78
Mulberry, 3 miles east of, 6 feet north of road, 160 feet east of gap, in vertical ledge of rock; aluminum tablet stamped "1807"......	1, 807. 324
Mulberry, 4 miles east of, north side of road, 0.3 mile from foot of mountain; cross on large rock......	1, 404. 47
Mulberry, 5 miles east of, 10 feet north of ford over Pinnacle Creek, about 7 feet above level of water; nail in root of sycamore tree......	1, 315. 55
Pineville, about 1 mile south of, 250 feet northeast of junction of Guyandot River and Pinnacle Creek, 10 feet east of road forks, in ledge of rock; aluminum tablet stamped "1308"......	1, 308. 4
Pineville, 2.5 miles east of, 8 feet north of road by persimmon tree, in clearing 500 feet east of woods; cross on rock......	1, 223. 8

McGraws west along roads to Jesse.[1]

McGraws, 1.5 miles west of, just at foot of mountain, 6 feet south of fork of second-class road to northeast, opposite blacksmith shop; cross on ledge of rock......	1, 556 28
McGraws, 2.6 miles west of, 250 yards northeast of Laurel Fork, 6 feet south of road and 18 feet west of creek; cross on rock......	1, 420. 73
McGraws, 4 miles west of, 300 feet west of Allen Branch, 8 feet north of road, about 3 feet above level of road, in rock; bronze tablet stamped "1413".	1, 409. 881

Beech Branch up Big Huff Creek to Trace Fork.

Cyclone, 6 miles east of, 600 feet below Lower Gap Branch, on east side of road up Big Huff Creek, 100 feet above D. H. Cook's store; iron post stamped "1068"......	1, 069. 100
Road fork, 1 mile above; nail in root of tall sycamore tree 50 feet to right of road up Big Huff Creek......	1, 221. 05

From its mouth up Toney Fork 2 miles (single spur line).

Cyclone, 7 miles east of, south side of Toney Fork of Huff Creek, about 2 miles above mouth, in ledge of rock; copper bolt stamped "U. S. G. S. 1234 Ft. B. M."......	1, 235. 989

[1] An excessive error has been distributed in this line.

From its mouth up Trace Branch of Elk Creek northeast over Divide and down Elk Trace to Big Huff Creek.

	Feet.
Christian, 7.5 miles northeast of, on south side of road, at ruins of old house; point on sandstone rock marked "U. S. B. M. 1574"	1,573.88
Lower Gap Branch, 600 feet below, on south side of road up Big Huff Creek; iron post stamped "1068"	1,069.100

MULLENS QUADRANGLE.

Point 2.5 miles south of Pineville east to Virginian Ry. at point 2.3 miles south of Mullens.

Pineville, 3.5 miles east of, south side of road, 600 feet west of Sugar Creek, just east of small drain; cross on large flat rock	1,334.80
Pineville, 5 miles east of, 15 feet southwest of bend in road where it rounds end of spur, about 0.25 mile south of schoolhouse, in rock; aluminum tablet stamped "1378"	1,378.431
Pineville, 5.3 miles east of, north side of road by gate, 100 feet southwest of house; cross on rock	1,358.02
Pineville, 8 miles east of, about 300 feet east of trail to south over river, 8 feet north of road, in rock; aluminum tablet stamped "1369"	1,369.643
Pineville, 10.2 miles east of, 2 feet south of road, about 200 feet southwest of Dogwood Spring; cross on rock	1,388.57
Pineville, 10.5 miles east of, 10 feet south of road, 50 feet south of large chestnut tree, 200 feet west of bridge; nail in root of maple tree (railroad bench mark)	1,383.78
Pineville, 11.4 miles east of, south end of east abutment to Virginian Ry. bridge over Barker Creek, about 450 feet west of main line of railroad, in top face; aluminum tablet stamped "1396"	1,396.401

Mullens south along Virginian Ry. to Herndon.

Mullens, 3.5 miles south of, 12 feet south of Virginian Ry. track, in sharp curve to left; oval on large flat rock	1,460.96
Mullens, 4.8 miles south of, at Taft's siding, 3.5 feet west of Virginian Ry. track, on top face of northwest abutment to railroad over Barker Creek; cross in concrete	1,518.02
Bud, 400 yards southeast of post office, 12 feet southeast of Virginian Ry., in top face of southeast abutment to railroad bridge over Barker Creek, in concrete; aluminum tablet stamped "1593"	1,593.846
Bud, 3.1 miles south of, 6 feet north of Virginian Ry. track; cross on ledge of rock	1,778.44
Herndon, about 500 feet northwest of water tank, 10 feet south of Virginian Ry. track, in top face of southeast abutment of railroad bridge over creek, in rock; aluminum tablet stamped "1878"	1,878.625

Mullens northeast along Virginian Ry. to Tams (Gulf post office).

Mullens, at bank building, top of north stone banister of steps of bank entrance, in rock; aluminum tablet stamped "1418"	1,418.692
Mullens, 3.1 miles east of, 5 feet south of railroad, about 2 feet below level of same, on lower face of southwest abutment to culvert, in concrete; aluminum tablet stamped "1474"	1,474.484
Mullens, 3.8 miles east of, 6 feet south of railroad, southeast corner of truss over Allen Fork; top of bolt through guard rail	1,492.91
Mullens, 7.2 miles east of, 8 feet west of railroad, about 300 feet north of old splash dam, in ledge of rock; aluminum tablet stamped "1561"	1,561.186

	Feet.
Mullens, 10.8 miles northeast of, 15 feet west of Virginian Ry. track, about 0.25 mile north of Berry bridge, in rock on bank; aluminum tablet stamped "1648"	1,648.355
Tams (Gulf post office), 40 feet west of station platform, 200 feet north of truss over Bailey Branch, about 6 feet above track, in wall of rock; aluminum tablet stamped "1735"	1,735.654

Mullens north along Virginian Ry. to Lester.

Mullens, 3.8 miles north of, northwest corner of top step to northeast abutment of bridge over Slab Fork, about 200 feet north of tunnel	1,560.63
Maben, 60 feet southeast of station, in end of concrete water conveyor from mill pond; bronze tablet stamped "1586"	1,586.595
Maben, 2.8 miles north of, southeast abutment to bridge over Old Slab Fork; southeast corner of third step down	1,673.60
Maben, 2.8 miles north of, 8 feet south of railroad, on second step down of southeast abutment of bridge over Old Slab Fork, in rock; bronze tablet stamped "1673"	1,674.110
Slab Fork, in front of station; top of rail	1,904
Slab Fork, 1 mile north of, about 250 yards south of switch, 6 feet east of railroad track; cross on ledge of rock marked "1986"	1,986.93
Lester, 120 feet west of railroad, about 400 feet southwest of station, north side of street, in store building; bronze tablet stamped "2030"	2,030.713

Maben northwest along Ritter's narrow-gage railroad to McGraws (an excessive error has been distributed in this line).

Maben, 4 miles northwest of, in top of gap, 6 feet west of narrow gauge railroad, in ledge of rock; bronze tablet stamped "2172"	2,173.195
Maben, 7.3 miles northwest of, 150 feet west of railroad crossing, 7 feet south of railroad, in ledge of rock; aluminum tablet stamped "1806"	1,806.412
Maben, 8.2 miles northwest of, about 200 feet southeast of road crossing, north end of small cut and 125 feet southeast of truss; cross on ledge of rock	1,794.51
McGraws, about 200 yards south of post office, 20 feet north of drain, 8 feet west of road; oval chiseled on ledge of rock	1,751.29
McGraws, 0.6 mile west of, just in Glen Gap, 6 feet south of road; cross on rock	1,974.24

Pinnacle Creek east along Micajah Ridge to tunnel.

Herndon, 5.5 miles west of, 75 feet north of house of Cosby Lambert, 5 feet south of county road, in sandstone ledge; aluminum tablet stamped "2255 1909"	2,254.180
Herndon, 4.7 miles west of, north side of road, 50 feet east of road forks, 75 feet west of schoolhouse, nail in wooden plug set in top of stone post; marked "U. S. B. M. 2373"	2,372.63
Herndon, 3.4 miles southwest of, 400 feet northwest of house in low gap, 200 feet south of road to west, west side of county road, on sandstone ledge; chiseled square	2,351.70
Herndon, 2.9 miles southwest of, west side of county road, 900 feet southwest of house of Mr. Steele, in sandstone ledge; aluminum tablet stamped "2392 1909"	2,391.679
Herndon, 1.7 miles west of, just north of county road, on sandstone rock, chiseled square	2,445.45

BALD KNOB QUADRANGLE.

Mouth of Whiteoak Creek up Coal River to Hazy Creek.

	Feet.
Orange, 0.5 mile north of post office, south side of Whiteoak Creek, 300 feet west of mouth of Little Whiteoak Creek, 0.2 mile east of mouth of Whiteoak Creek, in rock cliff; aluminum tablet stamped "734"	732.963
Mouth of Whiteoak Creek, 1.6 miles south of, 300 feet east of sharp bend in road to east, 2 feet south of road; cross on ledge of rock	748.79
Mouth of Whiteoak Creek, 2.8 miles south of, 3 feet west of river; nail in root of sycamore tree	751.27
Mouth of Whiteoak Creek, 6.3 miles south of, 6 feet east of road, 100 feet south of ford over river, about 0.25 mile south of Serg Creek; cross on rock.	788.95
Mouth of Whiteoak Creek, 7.3 miles south of, northwest corner of concrete culvert of Chesapeake & Ohio Railway over Bear Hollow, in top face; bronze tablet stamped "817"	815.983
Jarrolds Valley, 1 mile south of, on northeast corner of concrete abutment of bridge over Little Marsh Fork, in lower face; aluminum tablet stamped "855"	855.404
Jarrolds Valley, 3.2 miles south of, 6 feet west of railroad grade, 150 feet north of culvert, in sharp curve to right; cross on rock	900.06
Jarrolds Valley, 3.8 miles south of, on east top face of culvert over branch, in concrete; aluminum tablet stamped "918"	916.834
Jarrolds Valley, 5.5 miles south of, about 0.5 mile above Hecla post office, 6 feet east of road and between same and Marsh Fork; spike in root of beech tree	942.27
Jarrolds Valley, 6.1 miles south of, 200 feet west of road, about 10 feet west of Marsh Fork, about 0.25 mile north of Hazy Creek, in ledge of rock, near old sycamore snag; bronze tablet stamped "956"	954.950

Williamsport quadrangle.

BERKELEY COUNTY.

The elevations in the following list are based upon the 1903 adjustment of precise leveling.

The leveling was done by J. M. Harris in 1908 and by C. H. Semper in 1910.

WILLIAMSPORT QUADRANGLE.

Potomac River southwest along Cumberland Valley R. R. to Martinsburg.

	Feet.
Williamsport, 1.5 miles southwest of, near west end of railroad bridge No. 82-1, top of rail	380.8
Surface of water in Potomac River under bridge No. 82-1, August 5, 1908.	325
Williamsport, 2.3 miles southwest of, southwest corner of west bridge seat of railroad bridge No. 82-2, in top of; aluminum tablet stamped "363"	362.570
Williamsport, 3.4 miles southwest of, top of west foundation of water tank and north end of; marked "G.S.□B.M. 361"	361.40
Falling Waters, 500 feet east of, northeast corner of east bridge seat of railroad bridge No. 85; marked "G.S.□B.M. 359"	359.06
Falling Waters, in front of station; top of rail	372.3
Falling Waters, 0.6 mile southwest of, in top of center of south head wall of concrete box culvert under railroad at telephone pole 85,31; aluminum tablet stamped "404"	404.233

	Feet.
Bedington, 1,020 feet east of station, north side of track, in railroad concrete culvert; aluminum tablet stamped "387"	387,324
Bedington, in front of station; top of rail	392.5
Bedington, 270 feet west of station, south side of track; in top of railroad culvert; copper bolt (Pennsylvania R. R. bench mark)	392.036
Bedington, 0.3 mile south of, east side of north abutment of railroad bridge over creek, top of mud wall; marked "U.S.□B.M. 396"	395.96
Berkeley, 1,500 feet north of station, overhead bridge, in front face of east abutment; aluminum tablet stamped "471"	471.36
Berkeley, in front of station; top of rail	477.6

APPENDIX.

PRECISE LEVELING BY COAST AND GEODETIC SURVEY AND BALTIMORE & OHIO RAILROAD.

Blacksville, Cameron, Clarington, Elizabeth, Fairmont, Flintstone, Hancock, Harrisville, Keyser, Kingwood, Littleton, Mannington, Martinsburg, Middleton, Parkersburg, Pawpaw, Piedmont, Thornton, West Union, Wheeling, and Williamsport quadrangles.

BERKELEY, DODDRIDGE, HAMPSHIRE, HARRISON, JEFFERSON, MARION, MARSHALL, MINERAL, MONONGALIA, MORGAN, PRESTON, RITCHIE, TAYLOR, WETZEL, AND WOOD COUNTIES.

The following descriptions and elevations are extracted from reports of the Coast and Geodetic Survey and are here republished by permission of the Superintendent of that bureau. The bench marks were established by the Coast and Geodetic Survey and by the Baltimore & Ohio Railroad Co., and were included in the 1907 adjustment by the Coast and Geodetic Survey. The elevations are not likely to be changed by any future adjustment.

For convenient reference, as results in Bulletin 399 are based on the 1903 adjustment, the elevations of bench marks established previous to 1903 are given by both the 1903 and 1907 adjustments, in order to show the relative values by the two adjustments.

MIDDLETON QUADRANGLE.

Bench marks established at Harpers Ferry.

	Feet.
Harpers Ferry, on north side of tracks, almost directly across from Harpers Ferry signal tower, in capstone of north wing of west abutment of bridge; copper bolt (B. & O. bench mark 56A)	285.432
(1903 adjusted value=285.628.)	
Harpers Ferry, about 0.5 mile west of, 180 feet west of milepost "Baltimore 82 miles," in native rock on south side of tracks; copper bolt (B. & O. R. R. bench mark 57)	290.818
(1903 adjusted value=291.014.)	

MARTINSBURG QUADRANGLE.

Harpers Ferry northwest along Baltimore & Ohio R. R. to Martinsburg.

Engle, 1.8 miles east of, about 70 feet east of milepost "Baltimore 83 miles," in native rock on north side of tracks, about 8 feet from tracks; copper bolt (B. & O. bench mark 58)	309.940
(1903 adjusted value=310.139.)	
Engle, about 0.7 mile east of, on south side of tracks, in middle of coping of bridge 45; copper bolt (B. & O. bench mark 59)	354.745
(1903 adjusted value=354.946.)	

	Feet.
Engle, about 0.2 mile west of, about 30 feet west of milepost "Baltimore 85 miles," in native rock on south side of tracks; copper bolt (B. & O. bench mark 60)	386.541
(1903 adjusted value=386.744.)	
Engle, about 1.2 miles west of, about 600 feet east of milepost "Baltimore 86 miles," in native rock on north side of tracks; copper bolt (B. & O. bench mark 61)	411.223
(1903 adjusted value=411.433.)	
Duffields, about 1 mile east of, in south end of east wall of culvert 45G; copper bolt (B. & O. bench mark 62)	440.896
(1903 adjusted value=441.103.)	
Duffields, about 50 feet east of milepost "Baltimore 88 miles," in west end of north coping of culvert 45L; copper bolt (B. & O. bench mark 63)	484.269
(1903 adjusted value=484.479.)	
Shenandoah Junction, about 0.3 mile west of, about 400 feet west of milepost "Baltimore 89 miles," in native rock on south side of tracks; copper bolt (B. & O. bench mark 64)	530.635
(1903 adjusted value=530.848.)	
Shenandoah Junction, about 1.5 miles west of, about 500 feet west of milepost "Baltimore 90 miles," opposite telegraph pole 90–4 in a ledge of rock on north side of tracks; copper bolt (B. & O. bench mark 65)	560.324
(1903 adjusted value=560.539.)	
Hobbs, near, about 200 feet west of milepost "Baltimore 91 miles," in north end of west abutment of bridge 45; copper bolt (B. & O. bench mark 66)	583.929
(1903 adjusted value=584.145.)	
Kearneysville, about 0.3 mile south of, about 75 feet east of milepost "Baltimore 92 miles," in rock on north side of tracks; copper bolt (B. & O. bench mark 67)	564.417
(1903 adjusted value=564.635.)	
Kearneysville, about 1.2 miles north of, opposite milepost "Baltimore 93 miles," section of rail set vertically in ground (B. & O. bench mark 68)	528.360
(1903 adjusted value=528.580.)	
Van Clevesville, about 1.2 miles southeast of, opposite milepost "Baltimore 94 miles," section of rail set vertically in ground (B. & O. bench mark 69)	497.544
(1903 adjusted value=497.767.)	
Van Clevesville, about 0.2 mile south of, almost directly behind milepost "Baltimore 95 miles," in a large rock on north side of tracks; copper bolt (B. & O. bench mark 70)	478.086
(1903 adjusted value=478.311.)	
Van Clevesville, about 0.8 mile northwest of, 250 feet west of milepost "Baltimore 96 miles," in rock on south side of tracks; copper bolt (B. & O. bench mark 71)	450.599
(1903 adjusted value=450.827.)	
Van Clevesville, about 1.8 miles northwest of, about 500 feet west of milepost "Baltimore 97 miles," in west end of south coping of a culvert; copper bolt (B. & O. bench mark 72)	403.934
(1903 adjusted value=404.164.)	
Opequon, near, about 600 feet east of milepost "Baltimore 98 miles," on north side of tracks, on west end of coping of culvert at telegraph pole 97/34; copper bolt (B. & O. bench mark 73)	384.060
(1903 adjusted value=384.291.)	
Martinsburg, 0.7 mile east of, 240 feet west of milepost "Baltimore 99 miles," in middle of north coping of bridge 49.2; copper bolt (B. & O. bench mark 74)	399.334
(1903 adjusted value =399.568.)	

	Feet.
Martinsburg, about 0.2 mile west of station, about 280 feet east of milepost "Baltimore 100 miles," in middle of north coping of an arch; copper bolt (B. & O. bench mark 75)	432.911
(1903 adjusted value=433.147.)	
Martinsburg, about 1.5 miles northwest of, opposite milepost "Baltimore 101 miles," section of rail set vertically in ground (B. & O. bench mark 76)	469.660
(1903 adjusted value=469.899.)	

WILLIAMSPORT QUADRANGLE.

Martinsburg north along Baltimore & Ohio R. R. to Back Creek.

Martinsburg, about 2.5 miles northwest of, about 800 feet west of milepost "Baltimore 102 miles," in native rock on the north side of tracks; copper bolt (B. & O. bench mark 77)	490.259
(1903 adjusted value=490.500.)	
Tabb, near, about 40 feet east of milepost "Baltimore 103 miles," in native rock; copper bolt (B. & O. bench mark 78)	527.080
(1903 adjusted value=527.323.)	
Tabb, near, about 200 feet west of milepost "Baltimore 104 miles," in a large rock on north side of tracks; copper bolt (B. & O. bench mark 79)	522.637
(1903 adjusted value=522.883.)	
Tabb, about 1.2 miles northwest of, opposite milepost "Baltimore 105 miles;" section of rail set vertically in ground (B. & O. bench mark 80)	518.101
(1903 adjusted value=518.349.)	
North Mountain, about 1.2 miles southeast of, about 500 feet west of milepost "Baltimore 106 miles," between tracks in the bridge seat of the east abutment of bridge 52; copper bolt (B. & O. bench mark 81)	506.938
(1903 adjusted value=507.188.)	
North Mountain, about 0.2 mile south of station, 850 feet west of milepost "Baltimore 107 miles," between tracks in bridge seat of east abutment of bridge 52½; copper bolt (B. & O. bench mark 82)	527.896
(1903 adjusted value=528.149.)	
North Mountain, about 0.5 mile north of, opposite milepost "Baltimore 108 miles;" section of rail set vertically in ground (B. & O. bench mark 83)	528.471
(1903 adjusted value=528.726.)	
North Mountain, about 1.5 miles northwest of, about 100 feet east of milepost "Baltimore 109 miles;" section of rail set vertically in ground (B. & O. bench mark 84)	504.117
(1903 adjusted value=504.374.)	
Back Creek, near, opposite milepost "Baltimore 110 miles;" section of rail set vertically in ground (B. & O. bench mark 85)	461.841
(1903 adjusted value=462.100.)	

HANCOCK QUADRANGLE.

Back Creek northwest along Baltimore & Ohio R. R. to Sir Johns Run.

Back Creek, west of, in north end of the west abutment of bridge 53; copper bolt (B. & O. bench mark 86)	426.400
(1903 adjusted value=426.662.)	
Cherry Run, about 1.5 miles southeast of, opposite milepost "Baltimore 112 miles;" section of rail set vertically in ground between tracks (B. & O. bench mark 87)	391.637
(1903 adjusted value=391.900.)	
Cherry Run, about 0.6 mile east of, in south end of bridge seat of west abutment of bridge 54; copper bolt (B. & O. bench mark 88)	384.835
(1903 adjusted value=385.101.)	

	Feet.
Cherry Run, about 0.5 mile west of, opposite milepost "Baltimore 114 miles;" section of rail set vertically in ground (B. & O. bench mark 89).. (1903 adjusted value=396.865.)	396.597
Miller, near, opposite milepost "Baltimore 115 miles;" section of rail set vertically in ground (B. & O. bench mark 90)........................ (1903 adjusted value=404.608.)	404.338
Miller, near, opposite milepost "Baltimore 116 miles;" section of rail set vertically in ground (B. & O. bench mark 91)........................ (1903 adjusted value=396.575.)	396.303
Sleepy Creek, about 0.4 mile east of, opposite milepost "Baltimore 117 miles;" section of rail set vertically in ground (B. & O. bench mark 92).. (1903 adjusted value=399.461.)	399.187
Sleepy Creek, between tracks in bridge seat of east abutment of bridge 55; copper bolt (B. & O. bench mark 92A).............................. (1903 adjusted value=395.836.)	395.560
Sleepy Creek, 0.5 mile west of, opposite milepost "Baltimore 118 miles;" section of rail set vertically in ground (B. & O. bench mark 93).......... (1903 adjusted value=401.527.)	401.251
Sleepy Creek, about 1.5 miles west of, opposite milepost "Baltimore 119 miles;" section of rail set vertically in ground (B. & O. bench mark 94).. (1903 adjusted value=406.061.)	405.782
Sleepy Creek, about 2.5 miles west of, opposite milepost "Baltimore 120 miles;" section of rail set vertically in ground (B. & O. bench mark 95)... (1903 adjusted value=407.229.)	406.947
Hancock, about 2 miles east of, opposite milepost "Baltimore 121 miles;" section of rail set vertically in ground (B. & O. bench mark 96).......... (1903 adjusted value=405.341.)	405.058
Hancock, about 1 mile east of, opposite milepost "Baltimore 122 miles;" section of rail set vertically in ground (B. & O. bench mark 97).......... (1903 adjusted value=409.366.)	409.080
Hancock, west end of north coping of bridge 56; copper bolt (B. & O. bench mark 97A).. (1903 adjusted value=417.675.).	417.387
Hancock, about 0.2 mile west of, opposite milepost "Baltimore 123 miles;" section of rail set vertically in ground (B. & O. bench mark 98).......... (1903 adjusted value=419.034.)	418.746
Hancock, about 1.2 miles southwest of, opposite milepost "Baltimore 124 miles;" copper bolt set vertically in ground (B. & O. bench mark 99).... (1903 adjusted value=417.507.)	417.216
Round Top, about 1 mile northeast of, opposite milepost "Baltimore 125 miles;" section of rail set vertically in ground (B. & O. bench mark 100).. (1903 adjusted value=415.896.)	415.602
Round Top, opposite milepost "Baltimore 126 miles;" section of rail set vertically in ground (B. & O. bench mark 101)........................ (1903 adjusted value=426.927.)	426.630
Round Top, about 1 mile southeast of, 150 feet east of milepost "Baltimore 127 miles;" in a rock outcrop on the north side of the tracks; copper bolt (B. & O. bench mark 102).. (1903 adjusted value=426.670.)	426.370
Sir Johns Run, about 0.5 mile north of; opposite milepost "Baltimore 128 miles;" section of rail set vertically in ground (B. & O. bench mark 103).. (1903 adjusted value=425.247.)	424.944
Sir Johns Run, about 0.5 mile south of, 20 feet west of telegraph pole 128/38, in native rock on south side of tracks; copper bolt (B. & O. bench mark 104).. (1903 adjusted value=427.006.)	426.700

Sir Johns Run, about 0.5 mile south of, about 400 feet west of milepost "Baltimore 130 miles;" set in culvert coping on south side of tracks; copper bolt (B. & O. bench mark 105) .... Feet. 426.600
(1903 adjusted value=426.909.)

PAWPAW QUADRANGLE.

Great Cacapon west along Baltimore & Ohio R. R. to Little Cacapon.

Great Cacapon, 1 mile east of, about 200 feet east of milepost "Baltimore 131 miles," in large rock on north side of track; copper bolt (B. &. O. bench mark 106) 436.335
(1903 adjusted value=436.648.)

Great Cacapon, near, between tracks in bridge seat of east abutment of bridge 57 across Great Cacapon river; copper bolt (B. & O. bench mark 107) 435.613
(1903 adjusted value=435.929.)

Great Cacapon, about 1 mile west of, opposite milepost "Baltimore 133 miles;" section of rail set vertically in ground (B. & O. bench mark 108). 452.979
(1903 adjusted value=453.298.)

Woodmont, 0.3 mile west of, opposite milepost "Baltimore 134 miles;" section of rail set vertically in ground (B. & O. bench mark 109) 450.436
(1903 adjusted value=450.759.)

Lineburg, about 0.8 mile east of, opposite telegraph pole 135/4; copper bolt in rock on south side of tracks (B. & O. bench mark 110) 454.170
(1903 adjusted value=454.495.)

Lineburg, about 0.2 mile west of, opposite milepost "Baltimore 136 miles;" section of rail set vertically in ground (B. & O. bench mark 111) 458.213
(1903 adjusted value=458.541.)

Lineburg, about 1.2 miles south of, 25 feet east of milepost "Baltimore 137 miles," in a rock on south side of tracks; copper bolt (B. & O. bench mark 112) 468.730
(1903 adjusted value=469.061.)

Orleans Road, about 0.8 mile east of, opposite milepost "Baltimore 138 miles;" section of rail set vertically in ground (B. & O. bench mark 113).. 487.851
(1903 adjusted value=488.186.)

Orleans Road, about 0.3 mile south of, opposite milepost "Baltimore 139 miles;" section of rail set vertically in ground (B. & O. bench mark 114).. 504.276
(1903 adjusted value=504.613.)

Rockwells Run, near, 500 feet beyond milepost "Baltimore 140 miles;" in rock on south side of tracks; copper bolt (B. & O. bench mark 115)... 523.003
(1903 adjusted value=523.343.)

Doe Gully, opposite milepost "Baltimore 141 miles;" section of rail set vertically in ground (B. & O. bench mark 116) 546.651
(1903 adjusted value=546.995.)

Doe Gully, about 1 mile south of, opposite milepost "Baltimore 142 miles;" section of rail set vertically in ground (B. & O. bench mark 117) 544.057
(1903 adjusted value=544.404.)

Hansrotte, 1 mile northeast of, directly opposite milepost "Baltimore 143 miles;" in rock on south side of tracks; copper bolt (B. & O. bench mark 118) 520.465
(1903 adjusted value=520.815.)

Hansrotte, near, opposite milepost "Baltimore 144 miles;" section of rail set vertically in ground (B. & O. bench mark 119) 494.219
(1903 adjusted value=494.572.)

	Feet.
Hansrotte, about 1 mile west of, opposite milepost "Baltimore 145 miles;" section of rail set vertically in ground (B. & O. bench mark 120)........ (1903 adjusted value=498.242.)	497.885
Baird, near, opposite milepost "Baltimore 146 miles;" section of rail set vertically in ground (B. & O. bench mark 121)........................ (1903 adjusted value=498.003.)	497.643
Baird, about 1 mile southwest of, opposite milepost "Baltimore 147 miles;" section of rail set vertically in ground (B. & O. bench mark 122)........ (1903 adjusted value=490.256.)	489.894
Magnolia, about 1 mile northwest of, opposite milepost "Baltimore 148 miles;" section of rail set vertically in ground (B. & O. bench mark 123).. (1903 adjusted value=494.440.)	494.073
Magnolia, about 0.2 mile east of, 500 feet beyond milepost "Baltimore 149 miles;" on south side of tracks in east end of coping of bridge 47D; copper bolt (B. & O. bench mark 124)................................... (1903 adjusted value=498.004.)	497.631
Magnolia, about 1 mile southeast of, opposite milepost "Baltimore 150 miles;" section of rail set vertically in ground (B. & O. bench mark 125).. (1903 adjusted value=502.447.)	502.075
Magnolia, about 2 miles south of, opposite milepost "Baltimore 151 miles;" copper bolt in rock (B. & O. bench mark 126)........................ (1903 adjusted value=511.896.)	511.521
Pawpaw, about 1 mile north of, opposite milepost "Baltimore 152 miles," in a rock on south side of tracks; copper bolt (B. & O. bench mark 127).. (1903 adjusted value=516.603.)	516.225
Pawpaw, about 0.8 mile north of, opposite milepost "Baltimore 153 miles;" section of rail set vertically in ground (B. & O. bench mark 128)... (1903 adjusted value=527.034.)	526.652
Pawpaw, about 0.2 mile south of, opposite milepost "Baltimore 154 miles;" section of rail set vertically in ground (B. & O. bench mark 129)........ (1903 adjusted value=534.454.)	534.069
Pawpaw, 1.5 miles south of, opposite milepost "Baltimore 155 miles;" section of rail set vertically in ground (B. & O. bench mark 130)........ (1903 adjusted value=532.459.)	532.071
Little Cacapon, about 1 mile east of, about 500 feet east of milepost "Baltimore 156 miles," on south side of tracks in middle stone of coping of culvert; copper bolt (B. & O. bench mark 131)....................... (1903 adjusted value=529.243.)	528.852

FLINTSTONE QUADRANGLE.

Little Cacapon west along Baltimore & Ohio R. R. to Patterson Creek.

Little Cacapon, near, about 600 feet east of milepost "Baltimore 157 miles," between tracks in bridge seat of west abutment of bridge 59; copper bolt (B. & O. bench mark 132).. (1903 adjusted value=528.449.)	528.055
Okonoko, about 0.8 mile east of, opposite milepost "Baltimore 158 miles;" section of rail set vertically in ground (B. & O. bench mark 133)........ (1903 adjusted value=534.876.)	534.479
Okonoko, about 0.2 mile west of, about 800 feet east of milepost "Baltimore 159 miles;" copper bolt in north end of west abutment of bridge 60 (B. & O. bench mark 134).. (1903 adjusted value=538.769.)	538.369
Okonoko, about 1.2 miles southwest of, opposite milepost "Baltimore 160 miles;" section of rail set vertically in ground (B. & O. bench mark 135). (1903 adjusted value=537.486.)	537.083

	Feet.
French, about 0.4 mile east of, opposite milepost "Baltimore 161 miles;" section of rail set vertically in ground (B. & O. bench mark 136)....... (1903 adjusted value=541.194.)	540.787
French, about 0.8 mile west of, between tracks; copper bolt in a bridge seat of the east abutment of bridge 61A (B. & O. bench mark 137)........... (1903 adjusted value=554.416.)	554.005
French, about 1.8 miles west of, near west end of a cut near where milepost "Baltimore 163 miles" would be if planted, in rock on south side of tracks; copper bolt (B. & O. bench mark 138)........................ (1903 adjusted value=556.634.)	556.221
Green Spring, near, at milepost "Baltimore 164 miles," on south side of tracks in center of coping of culvert 62; copper bolt (B. & O. bench mark 139).. (1903 adjusted value=552.351.)	551.935
Green Spring, about 1 mile west of, opposite milepost "Baltimore 165 miles;" section of rail set vertically in ground (B. & O. bench mark 140). (1903 adjusted value=559.656.)	559.237
Green Spring, about 2 miles west of, opposite milepost "Baltimore 166 miles;" section of rail set vertically in ground (B. & O. bench mark 141). (1903 adjusted value=562.497.)	562.075
Green Spring, about 3 miles west of, opposite milepost "Baltimore 167 miles;" section of rail set vertically in ground (B. & O. bench mark 142). (1903 adjusted value=560.101.)	559.676
Dans Run, opposite milepost "Baltimore 168 miles;" section of rail set vertically in ground (B. & O. bench mark 143)....:.................... (1903 adjusted value=565. 281.)	564.852
Dans Run, about 1 mile west of, opposite milepost "Baltimore 169 miles;" section of rail set vertically in ground (B. & O. bench mark 144)........ (1903 adjusted value 566.310.)	565.879
Patterson Creek Cut-Off, about 0.5 mile east of bridge, opposite milepost "Baltimore 170 miles;" section of rail set vertically in ground (B. & O. bench mark 145).. (1903 adjusted value=568.009.)	567.574
Patterson Creek Cut-Off, south end of west abutment of railroad bridge over Patterson Creek (U. S. G. S. bench mark, 574 Patterson Creek)......... (1903 adjusted value=574.242.)	573.805
Patterson Creek Cut-Off, between tracks, in a bridge seat of the east abutment of bridge 63; copper bolt (B. & O. bench mark 145A)............. (1903 adjusted value=569.372.)	568.935
Patterson Creek, about 0.3 mile northwest of, opposite milepost "Baltimore 171 miles;" section of rail set vertically in ground (B. & O. bench mark 146).. (1903 adjusted value=575.601.)	575.163

KEYSER QUADRANGLE.

Bench marks established along Baltimore & Ohio R. R. near Keyser.

Keyser, near, opposite telegraph pole 201/8 set between tracks in south abutment of bridge· copper bolt (B. & O. bench mark 22)..............	800.702
Keyser, near center of Keyser yards, opposite milepost 202; section of rail set vertically in ground (B. & O. bench mark 23).....................	826.999
Keyser, near, at northwest end of Keyser yards, opposite milepost 203; section of rail set vertically in ground (B. & O. bench mark 24).........	837.595
Keyser, near, opposite milepost 204; section of rail set vertically between tracks (B. & O. bench mark 25)...................................	854.580

PIEDMONT QUADRANGLE.

Bench marks established along Baltimore & Ohio R. R. near Piedmont.

	Feet.
Piedmont, near, in bridge seat of abutment at telegraph pole 204/30; copper bolt (B. & O. bench mark 26)	871.280
Piedmont, near, at telegraph pole 205/21, in abutment of bridge; copper bolt (B. & O. bench mark 26A)	889.273
Piedmont, 0.5 mile southeast of, opposite milepost 206; section of rail set vertically between tracks (B. & O. bench mark 27)	906.085
Piedmont, 0.5 mile southwest of, opposite milepost 207; section of rail set vertically in ground between tracks (B. & O. bench mark 28)	932.914
West Virginia Central Junction, 400 feet west of, in southwest end of bridge seat northwest abutment of bridge for siding over Potomac River; copper bolt (B. & O. bench mark 28A)	948.302

KINGWOOD QUADRANGLE.

Corinth west along Baltimore & Ohio R. R. to Rowlesburg.

Corinth, 0.2 mile northwest of, in bridge at telegraph pole 238/20; copper bolt (B. & O. bench mark 59A)	2,434.838
Rinard, near, opposite milepost 239; section of rail set vertically in ground between tracks (B. & O. bench mark 60)	2,452.555
Riggs, 0.5 mile east of, 250 feet west of milepost 240 on arch culvert; copper bolt (B. & O. bench mark 61)	2,481.523
Terra Alta, 1 mile southeast of, opposite milepost 241; section of rail set vertically in ground between tracks (B. & O. bench mark 62)	2,524.106
Terra Alta, 500 feet east of station, opposite milepost 242; section of rail set vertically in ground between tracks (B. & O. bench mark 63)	2,545.238
Terra Alta, 0.8 mile northwest of, in small bridge, at telegraph pole 242/35; copper bolt (B. & O. bench mark 64)	2,512.747
Terra Alta, 1.5 miles west of, in foundation of south side of east portal of tunnel; copper bolt (B. & O. bench mark 65)	2,395.471
Terra Alta, 3 miles southwest of, opposite milepost 245; section of rail set vertically in ground between tracks (B. & O. bench mark 66)	2,263.209
Terra Alta, 4 miles southwest of, opposite milepost 246; section of rail set vertically in ground between tracks (B. & O. bench mark 67)	2,146.947
Rodamers, 1 mile southwest of, telegraph pole 246/26, south side of west portal of Rodamers tunnel, in foundation; copper bolt (B. & O. bench mark 68)	2,091.207
Amblersburg, 2.5 miles northeast of, opposite milepost 248; section of rail set vertically in ground between tracks (B. & O. bench mark 69)	1,928.323
Amblersburg, 1.5 miles northeast of, opposite milepost 249; section of rail set vertically in ground between tracks (B. & O. bench mark 70)	1,811.555
Amblersburg, 0.5 mile northeast of, opposite milepost 250; section of rail set vertically in ground between tracks (B. & O. bench mark 71)	1,697.547
Amblersburg, telegraph pole 250/27, in bridge; copper bolt (B. & O. bench mark 72)	1,623.627
Amblersburg, about 1 mile southwest of, west of tracks, at telegraph pole 251/30, 15 feet from north end of retaining wall; copper bolt (B. & O. bench mark 73)	1,516.343
Rowlesburg, 1.8 miles northeast of, in bridge 91 at telegraph pole 252/17½; copper bolt (B. & O. bench mark 74)	1,473.168
Rowlesburg, 1.2 miles northeast of, opposite milepost 253; section of rail set vertically in ground between tracks (B. & O. bench mark 74A)	1,450.370

	Feet.
Rowlesburg, near, north of tracks in mud wall of east abutment of Cheat River bridge; copper bolt (B. & O. bench mark 75)	1,400.857
Rowlesburg, 1 mile west of, 40 feet east of telegraph pole 255/14; copper bolt set in rock (B. & O. bench mark 76)	1,490.643
Rowlesburg, 1.5 miles west of, telegraph pole 255/25, in center of capstone, north end of long retaining wall east of tracks; copper bolt (B. & O. bench mark 76A)	1,528.744
Rowlesburg, 2 miles northwest of, copper bolt set in east wing wall of north abutment of viaduct at telegraph pole 256/5 (B. & O. bench mark 77)	1,581.092

Point near Rowlesburg along Baltimore & Ohio R. R. to point 3.2 miles west of Rowlesburg.

Rowlesburg, 4 miles east of, on coping stone of abutment at northwest corner of Baltimore & Ohio R. R. bridge over Salt Lick Creek; chiseled square, C. & G. S. bench mark L	1,623.664
(1903 adjusted value = 1,624.164.)	
Rowlesburg, at base of center pillar at west end of Baltimore & Ohio R. R. bridge over Cheat River; chiseled square, marked "B.M." C. & G. S. bench mark XXVIII	1,400.333
(1903 adjusted value = 1,400.839.)	
Rowlesburg, 3.2 miles west of, on top of "Buckhorn Wall," about 131 feet from its eastern end; chiseled square marked "B.M." C. & G. S. bench mark XXIX	1,716.956
(1903 adjusted value = 1,717.467.)	

FAIRMONT QUADRANGLE.

Grafton along Baltimore & Ohio R. R. to Bridgeport.

Grafton, on top of north side of central pier of Baltimore & Ohio R. R. bridge over Taggarts Valley Creek, a branch of the Monongahela River; chiseled square. C. & G. S. bench mark M	996.303
(1903 adjusted value = 996.856.)	
Grafton, about 5.5 miles west of, cut on corner stone of east end of trestle 2½; chiseled square marked "B.M." C. & G. S. bench mark XXXI	1,082.088
(1903 adjusted value = 1,082.623.)	
Bridgeport, on corner stone of west abutment of Baltimore & Ohio R. R. bridge; chiseled square marked "B.M." C. & G. S. bench mark XXXII	979.135
(1903 adjusted value = 979.626.)	

Grafton northwest along Baltimore & Ohio R. R. to Fairmont.

Grafton, on Parkersburg branch, in north end of bridge seat of east abutment of bridge over Tygart River; copper bolt (B. & O. bench mark 102)	995.049
Grafton, 1 mile west of, near milepost 281; section of rail set vertically in ground between tracks (B. & O. bench mark 103)	991.794
Fetterman, in bridge 102; copper bolt (B. & O. bench mark 103A)	982.620
Fetterman, 0.5 mile north of, in northwest end of northeast wing wall, northwest abutment of bridge 103; copper bolt (B. & O. bench mark 104)	988.797
Fetterman, 1.2 miles northwest of, at milepost 283; section of rail set vertically in ground between tracks (B. & O. bench mark 105)	989.901
Fetterman, 1.8 miles northwest of, on culvert at telegraph pole 283/20; copper bolt (B. & O. bench mark 105A.)	982.195

	Feet.
Fetterman, 2.5 miles north of, on culvert at telegraph pole 284/11; copper bolt (B. & O. bench mark 106)	980.646
Bush, about 3 miles southeast of Valley Falls, bridge seat at northeast corner of girder bridge 104, 7 feet east of center of track, 4 feet below top of outer rail of curve; bronze tablet stamped "986 Pittsburg 1899." (B. & O. bench mark 107; U. S. G. S. bench mark)	985.048
Bush, near, on bridge at telegraph pole 285/28; copper bolt (B. & O. bench mark 107A)	979.827
Bush, 0.5 mile northwest of, on culvert at telegraph pole 286/10; copper bolt (B. & O. bench mark 108)	981.901
Valley Falls, about 1 mile east of, at milepost 287; section of rail set vertically in ground between tracks (B. & O. bench mark 109)	982.910
Valley Falls, 50 feet west of milepost 288 in native rock north of track; copper bolt (B. & O. bench mark 110)	974.153
Valley Falls, 1 mile northwest of, near milepost 289 in northwest end of southwest coping of arch bridge 105; copper bolt (B. & O. bench mark 111)	944.936
Hammond, 0.2 mile northwest of, on arch bridge 107; copper bolt (B. & O. bench mark 112)	937.853
Hammond, 1 mile west of, at telegraph pole 290/20; rail section set northwest of tracks (B. & O. bench mark 113)	914.434
Powells, 0.5 mile northwest of, on bridge 108, at telegraph pole 291/28; copper bolt (B. &. O. bench mark 114)	898.424
Powells, 1.5 miles northwest of, 35 feet west of telegraph pole 292/14, in native rock; copper bolt (B. &. O. bench mark 115)	898.887
Colfax, 1.2 miles southeast of, on arch culvert at telegraph pole 293/11; copper bolt (B. & O. bench mark 116)	889.443
Colfax, in center of north capstone of west coping of bridge 109; copper bolt (B. & O. bench mark 117)	888.517
Colfax, 1 mile northwest of, near southwest end of northwest coping of arch culvert at telegraph pole 295/17, copper bolt (B. & O. bench mark 118)	885.389
Bentons Ferry, 1 mile east of, in arch culvert at telegraph pole 296/20; copper bolt (B. & O. bench mark 119)	887.132
Bentons Ferry, at telegraph pole 297/22, in north end of east wing wall of north abutment of bridge 111; copper bolt (B. &. O. bench mark 120)	888.355
Bentons Ferry, 160 feet west of signboard, bridge seat at southeast corner of small girder bridge 111, 4.5 feet below top of rail, 18.5 feet south of center of track; bronze tablet stamped "885 Pittsburg 1899" (U. S. G. S. bench mark)	884.546
Kingmont, north of tracks at telegraph pole 298/20; rail section (B. & O. bench mark 121)	888.303
Kingmont, 1 mile northeast of, on large arch culvert at telegraph pole 299/21; copper bolt (B. & O. bench mark 122)	881.560
Kingmont, 1.5 miles northeast of, on arch culvert at telegraph pole 299/37; copper bolt (B. & O. bench mark 122A)	881.332
Gaston Junction, in west end of bridge seat, north abutment of bridge 112 over Monongahela River; copper bolt (B. & O. bench mark 123)	885.248
Fairmont, between tracks in southwest end of pier for overhead highway bridge; copper bolt (B. & O. bench mark 124)	886.621
Fairmont, 1 mile west of, in northwest end of bridge seat, southwest abutment of Fairmont, Morgantown & Pittsburg Bridge over Monongahela River; copper bolt (B. & O. bench mark 125)	884.230
Fairmont, near, in south end of bridge seat of east abutment of bridge to Fairmont roundhouse; copper bolt (B. & O. bench mark 125A)	868.668

THORNTON QUADRANGLE.

Bench mark near Grafton.

	Feet.
Grafton, about 2 miles east of, on corner stone of abutment of small bridge; chiseled square. (B. & O. and C. & G. S. bench mark XXX) (1903 adjusted value = 1,024.024.)	1,023.475

Austen west along Baltimore & Ohio R. R. to Grafton.

Rowlesburg, 3 miles west of, at telegraph pole 257/9; copper bolt set in rock (B. & O bench mark 78)	1,695.877
Buckhorn, 0.2 mile northwest of, 40 feet southeast of telegraph pole 257/20, in northwest end of retaining wall, northeast of tracks; copper bolt (B. & O. bench mark 78A)	1,724.878
Buckhorn, 1 mile northwest of, 40 feet northwest of telegraph pole 258/7; copper bolt set in rock (B. & O. bench mark 79)	1,799.779
Anderson, about 0.2 mile west of, at milepost "Baltimore 259"; section of rail set vertically in ground between tracks (B. & O. bench mark 80)	1,857.241
Tunnelton, 0.8 mile southeast of, at milepost "Baltimore 260"; section of rail set vertically in ground between tracks (B. & O. bench mark 81)	1,828.379
Tunnelton, about 0.2 mile west of, in first step of retaining wall north of tracks at east portal of Kingwood tunnel; copper bolt (B. & O. bench mark 82)	1,826.434
Tunnelton, about 1 mile west of, at west end of Kingwood tunnel; section of rail set vertically in ground between tracks (B. & O. bench mark 83)	1,783.651
West End, 300 feet west of, in abutment of bridge; copper bolt (B. & O. bench mark 83A)	1,742.710
Austen, about 1 mile east of, 40 feet south of tracks, near telegraph pole 263/12; copper bolt set in rock (B. & O. bench mark 84)	1,627.886
Austen, 0.2 mile east of, 50 feet west of Murray tunnel; copper bolt set in rock (B. & O. bench mark 85)	1,552.695
Austen, 0.8 mile west of, at milepost 265; section of rail set vertically in ground between tracks (B. & O. bench mark 86)	1,443.864
Newburg, near, at milepost 266; section of rail set vertically in ground between tracks (B. & O. bench mark 87)	1,338.506
Newburg, near, in seat of bridge 95; copper bolt (B. & O. bench mark 88)	1,244.992
Independence, 1 mile southwest of, at milepost 269; section of rail set vertically in ground between tracks (B. & O. bench mark 90)	1,147.326
Hardman, near, in seat of bridge 97; copper bolt (B. & O. bench mark 91)	1,108.151
Ironton, 1 mile northeast of, nearly opposite milepost 271, in large rock about 100 feet southeast of tracks; copper bolt (B. & O. bench mark 92)	1,101.465
Ironton, near, at telegraph pole 271/37; copper bolt in rock 50 feet southeast of tracks (B. & O. bench mark 93)	1,074.795
Ironton, 0.8 mile southwest of, in abutment of pipe culvert at telegraph pole 272/26; copper bolt (B. & O. bench mark 94)	1,064.449
Thornton, 1 mile northeast of, at telegraph pole 273/25; section of rail set vertically in ground between tracks (B. & O. railroad bench mark 95)	1,051.731
Thornton, in abutment of bridge 99; copper bolt (B. & O. bench mark 96)	1,040.166
Thornton, 0.8 mile southwest of, opposite telegraph pole 275/15; section of rail set vertically in ground between tracks (B. & O. bench mark 97)	1,039.659
Thornton, 1.6 miles west of, in southwest end of bridge seat of southeast abutment of bridge at telegraph pole 276/8; copper bolt (B. & O. bench mark 98)	1,034.079
Thornton, 2.5 miles west of, nearly opposite telegraph pole 277/5; copper bolt set in rock (B. & O. bench mark 99)	1,034.126

	Feet.
Grafton, about 2 miles east of, east abutment of bridge 100, set between tracks in bridge seat; copper bolt (B. & O. bench mark 100)	1,021.293
Grafton, 1.2 miles east of, at milepost 279; section of rail set vertically in ground between tracks (B. & O. bench mark 101)	1,007.141

WEST UNION QUADRANGLE.

Bridgeport along Baltimore & Ohio R. R. to point 10 miles west of West Union.

West Union, about 2 miles east of, on top of pier at west end of Baltimore & Ohio R. R. bridge 21, over Middle Island Creek; chiseled square marked "B. M.," C. & G. S. bench mark XXXIII	799.797
(1903 adjusted value=800.186.)	
West Union, about 0.2 mile east of, on top of southwest corner of pier of Baltimore & Ohio R. R. bridge 23, over Middle Island Creek; chiseled square marked "U. S. C. & G. S.," C. & G. S. bench mark N	804.478
(1903 adjusted value=804.862.)	
West Union, about 10 miles west of, on southeast corner stone of pier of Baltimore & Ohio R. R. bridge 26; chiseled square marked "B. M.," C. & G. S. bench mark XXXIV	802.468
(1903 adjusted value=802.817.)	

HARRISVILLE QUADRANGLE.

Cornwall east along Baltimore & Ohio R. R. to point near Cairo.

Cornwall station, about 0.2 mile east of, on coping stone of the east abutment of Baltimore & Ohio R. R. bridge 31, over Bonds Creek; chiseled square marked "B. M.," C. & G. S. bench mark XXXV	693.562
(1903 adjusted value=693.866.)	
Cairo, 1 mile east of, over Bonds Creek, on east abutment of Baltimore & Ohio R. R. bridge 35; chiseled square marked "B. M.," C. & G. S. bench mark XXXVI	685.656
(1903 adjusted value=685.954.)	

ELIZABETH QUADRANGLE.

Bench marks established near Petroleum.

Petroleum, about 655 feet east of, on west abutment of Baltimore & Ohio R. R. bridge over Goose Creek; chiseled square marked "B. M.," C. & G. S. bench mark XXXVII	696.663
(1903 adjusted value=696.933.)	
Petroleum, about 1 mile west of, on northeast corner stone of abutment of Baltimore & Ohio R. R. bridge 44; chiseled square marked "B. M.," C. & G. S. bench mark XXXVIII	692.904
(1903 adjusted value=693.171.)	

PARKERSBURG QUADRANGLE.

Bench marks established near Parkersburg.

Parkersburg, 2 miles east of, on foundation at northwest corner of Baltimore & Ohio R. R. bridge 52; square cut, C. & G. S. bench mark XXXIX	607.255
(1903 adjusted value=607.454.)	
Parkersburg, on water table, south front, near western corner of courthouse; chiseled square marked "U. S. C. & G. S. B. M."	615.612
(1903 adjusted value, C. & G. S. bench mark O=615.800.)	

BLACKSVILLE QUADRANGLE.

Barnesville west along Baltimore & Ohio R. R. to Underwood.

	Feet.
Barnesville, 0.5 mile east of, in south end of small culvert at telegraph pole 304/5; copper bolt (B. & O. bench mark 126)	873.544
Barnesville, 0.5 mile northwest of; copper bolt set in stone pier east of tracks at Fairmont Coal Co. shaft mine (B. & O. bench mark 127)	878.389
Barrackville, 1.5 miles east of, at telegraph pole 305/30; rail section set southeast of track (B. & O. bench mark 128)	887.438
Barrackville, 0.8 mile southeast of, close to north truss of bridge at telegraph pole 306/24, in bridge seat, west abutment; copper bolt (B. & O. bench mark 129)	893.945
Barrackville, at station, in south end of bridge seat, west abutment of bridge 115; copper bolt (B. & O. bench mark 130)	901.476
Barrackville, 1 mile southwest of, on bridge seat of abutment of bridge at telegraph pole 308/18; copper bolt (B. & O. bench mark 131)	909.237
Barrackville, 1.8 miles west of, in abutment of pipe culvert at telegraph pole 309/10; copper bolt (B. & O. bench mark 132)	913.367
Katy, near, just northeast of tracks, in bridge seat, northwest abutment, at telegraph pole 310/22; copper bolt (B. & O. bench mark 133)	919.178
Underwood (Farmington), 1.8 miles east of, in abutment on bridge 116 at telegraph pole 311/5; copper bolt (B. & O. bench mark 134)	922.463
Underwood (Farmington), 0.8 mile east of, at milepost 312; rail section set on southwest side of tracks (B. & O. bench mark 135)	931.767

MANNINGTON QUADRANGLE.

Underwood northwest along Baltimore & Ohio R. R. to Hundred.

Underwood (Farmington), in abutment of bridge 116¼; copper bolt (B. & O. bench mark 131)	934.563
Underwood (Farmington), 0.6 mile west of, in abutment of bridge 116½, at telegraph pole 313/15; copper bolt (B. & O. bench mark 137)	937.233
Underwood (Farmington), 1.5 miles west of, in southeast end of northeast abutment of small bridge at telegraph pole 314/9; copper bolt (B. & O. bench mark 138)	940.335
Downs (Bloomfield), 1.2 miles southeast of, in bridge seat of abutment of bridge 117, at telegraph pole 315/12; copper bolt (B. & O. bench mark 139).	948.159
Downs (Bloomfield), 1 mile southeast of, in bridge seat of abutment of bridge 118, telegraph pole 315/23; copper bolt (B. & O. bench mark 139A)	953.073
Downs (Bloomfield), 1 mile southeast of, 2.8 miles west of Farmington; chiseled square on abutment of bridge, marked "953" (U. S. G. S. bench mark)	953.095
Downs (Bloomfield), near station; copper bolt set in bridge seat of abutment of bridge 118½ (B. & O. bench mark 140)	962.197
Downs (Bloomfield), 0.8 mile west of, in bridge seat of abutment of bridge at telegraph pole 317/11; copper bolt (B. & O. bench mark 141)	962.964
Mannington, 1.8 miles southeast of, in east end of bridge seat, north abutment of highway bridge near milepost 318; copper bolt (B. & O. bench mark 142)	968.719
Mannington, 0.8 mile southeast of, in bridge seat of abutment of bridge at telegraph pole 319/9; copper bolt (B. & O. bench mark 143)	969.953
Mannington, northeast corner of front step of Exchange Bank (B. & O. bench mark 144)	974.486

Fe

Mannington, in pillar north of door of Exchange Bank; bronze tablet stamped "975 Grafton 1902" (U. S. G. S. bench mark) .... 974.

Mannington, 1 mile north of, in bridge seat of abutment of bridge 119; copper bolt (B. & O. bench mark 145) .... 974.

Mannington, 1.5 miles northwest of, near telegraph pole 321/23, in bridge seat of abutment of bridge 120; copper bolt (B. & O. bench mark 146) .... 981.

Mannington, 2.2 miles northwest of, in bridge seat of abutment of bridge 121; copper bolt (B. & O. bench mark 147) .... 989.

Mannington, 2.8 miles northwest of, between track and east truss in bridge seat north abutment bridge 123; copper bolt (B. & O. bench mark 148) .... 991.

Metz, 0.8 mile south of, at telegraph pole 323/30; rail section set east of tracks (B. & O. bench mark 149) .... 999.

Metz, 0.2 mile north of, in abutment of bridge at telegraph pole 324/25; copper bolt (B. & O. bench mark 150) .... 1,003.

Metz, 1.5 miles northwest of, set in abutment of bridge at milepost 326; copper bolt (B. & O. bench mark 151) 1,017.8

Glover Gap, 0.2 mile southeast of, at milepost 327; rail section set south of tracks (B. & O. bench mark 152) 1,035.1

Glover Gap, 0.8 mile northwest of, at milepost 328; rail section set south of tracks (B. & O. bench mark 153) 1,057.7

Glover Gap, 1.2 miles northwest of, in north corner of small culvert at telegraph pole 328/24; copper bolt (B. & O. bench mark 153A) 1,084.9

Glover Gap, 2 miles northwest of, in abutment of bridge at telegraph pole 329/10; copper bolt (B. & O. bench mark 154) 1,118.9

Cottontown, 0.8 mile south of, 0.5 mile north of Burton tunnel, in large arch bridge 126; copper bolt (B. & O. bench mark 155) 1,126.3

Cottontown, copper bolt set in abutment of bridge near telegraph pole 331/5 (B. & O. bench mark 156) 1,090.6

Burton, between main track and east bound siding, in bridge seat, northwest abutment of bridge, at telegraph pole 331/27; copper bolt (B. & O. bench mark 157) 1,065.2

Burton, 0.9 mile northwest of, in west wing of south end stone face for pipe culvert at telegraph pole 332/23; copper bolt (B. & O. bench mark 158) 1,039.1

Hundred, 0.8 mile southeast of, in northwest end of southwest coping of box culvert at telegraph pole 333/5; copper bolt (B. & O. bench mark 159) 1,030.1

Hundred, just west of, in northeast end of northwest bridge seat of bridge 128; bronze tablet stamped "1013 Grafton 1902" (U. S. G. S. bench mark, B. & O. bench mark 160) 1,012.8

Hundred, 1.2 miles northwest of; copper bolt set in north end of west bridge seat of bridge at telegraph pole 335/7 (B. & O. bench mark 161) 995.5

Hundred, 1.8 miles northwest of, at telegraph pole 335/23, in abutment of bridge 130; copper bolt (B. & O. bench mark 161A) 986.1

LITTLETON QUADRANGLE.

Littleton northwest along Baltimore & Ohio R. R. to Bellton.

Littleton, 1.8 miles east of, set in abutment of bridge 131, at telegraph pole 336/21; copper bolt (B. & O. bench mark 162) 969.2

Littleton, 0.8 mile east of, telegraph pole 337/3, in abutment of bridge 133; copper bolt (B. & O. bench mark 163) 950.4

Littleton, 0.5 mile east of, in abutment of bridge 135; copper bolt (B. & O. bench mark 163A) 944.5

Littleton, between main track and siding at milepost 338; rail section (B. & O. bench mark 164) 941.3

	Feet.
Littleton, 0.8 mile northwest of, south of track at milepost 339; rail section (B. & O. bench mark 165)	1,016.194
Board Tree, 0.8 mile south of; center line pin at south end of Board Tree tunnel (B. & O. bench mark 166)	1,108.867
Board Tree, 0.2 mile south of, in rock projecting from under west end of first course of retaining wall at north end of Board Tree tunnel, east of track; copper bolt (B. & O. bench mark 167)	1,083.904
Board Tree, 0.5 mile northwest of, at telegraph pole 341/30; rail section set north of tracks (B. & O. bench mark 168)	1,012.274
Bellton, 1.4 miles southeast of, north of tracks at telegraph pole 343/4; rail section (B. & O. bench mark 169)	933.187
Bellton, 0.5 mile south of, between main track and siding at milepost 344; rail section (B. & O. bench mark 170)	897.539

CAMERON QUADRANGLE.

Bellton northwest along Baltimore & Ohio R. R. to Moundsville.

Denver station (Bellton), near, in abutment of bridge 136; copper bolt (B. & O. bench mark 170A)	889.040
Denver station, 0.8 mile north of Bellton, just south of present track, in bridge seat of east abutment of bridge 137; copper bolt (B. & O. bench mark 171)	910.867
Woodruff, 0.1 mile south of, east of tracks at milepost 346; rail section (B. & O. bench mark 172)	946.851
Woodruff, 0.9 mile north of, east of track at milepost 347; rail section (B. & O. bench mark 173)	1,011.739
Cogley, 0.5 mile south of, between main track and siding at milepost 348; rail section (B. & O. bench mark 174)	1,087.427
Cogley, 0.5 mile north of, east of tracks at milepost 349; rail section (B. & O. bench mark 175)	1,168.139
Cameron, 2 miles southeast of, east of tracks at north end of Welling tunnel; rail section (B. & O. bench mark 176)	1,199.225
Cameron, 1 mile east of, set north of tracks at telegraph pole 350/30; rail section (B. & O. bench mark 177)	1,125.450
Cameron, 0.2 mile east of, in south end of south wing wall, west abutment of bridge 138; copper bolt (B. & O. bench mark 178)	1,062.823
Cameron, 1 mile west of, between main track and siding at telegraph pole 352/30; rail section (B. & O. bench mark 179)	1,034.957
Loudenville, set in northeast end of northwest bridge seat of bridge 139; copper bolt (B. & O. bench mark 180)	995.771
Loudenville, 0.8 mile west of, in north end of west bridge seat of bridge at telegraph pole 354/27; copper bolt (B. & O. bench mark 181)	986.427
Glen Easton, 1.1 miles east of, in culvert at telegraph pole 355/10; copper bolt (B. & O. bench mark 182)	977.933
Glen Easton, 0.2 mile east of, in south end of bridge seat of west abutment of bridge 141; copper bolt (B. & O. bench mark 183)	964.700
Glen Easton, 0.8 mile northwest of, in northeast end of northwest bridge seat of bridge at telegraph pole 357/12; copper bolt (B. & O. bench mark 184)	926.535
Glen Easton, 1.1 miles northwest of, on abutment of bridge at telegraph pole 357/27; copper bolt (B. & O. bench mark 184A)	927.090
Glen Easton, 2.1 miles northwest of, in south end of west bridge seat of bridge 143, at telegraph pole 358/26; copper bolt (B. & O. bench mark 185)	902.384

	Feet.
Rosbys Rock, 2.5 miles east of, in south capstone of west abutment of bridge 145; at telegraph pole 359/30; copper bolt (B. & O. bench mark 186)	861.846
Rosbys Rock, 2 miles east of, in southeast corner of small culvert just east of Shepherds tunnel; copper bolt (B. & O. bench mark 187)	847.609
Rosbys Rock, 1 mile east of, in east end of south bridge seat at telegraph pole 361/9; copper bolt (B. & O. bench mark 188)	804.439
Rosbys Rock, 0.5 mile east of, in north end of east bridge seat of bridge at telegraph pole 361/25; copper bolt (B. O. bench mark 189)	789.009
Rosbys Rock, 0.5 mile northwest of, east of track at telegraph pole 362/25; rail section (B. & O. bench mark 190)	764.414
Rosbys Rock, 1.5 miles northwest of, northeast of track at telegraph pole 363/25; rail section (B. & O. bench mark 191)	741.743
Rosbys Rock, 2.5 miles northwest of, in north end of west wing of north abutment of bridge at telegraph pole 364/25; copper bolt (B. & O. bench mark 192)	718.217
Rosbys Rock, 4 miles northwest of, at telegraph pole 365/40, in north end of southeast abutment of bridge 146; square cut (B. & O. bench mark 193; U. S. G. S. bench mark)	680.494
Moundsville, 1.5 miles southeast of, west of tracks at telegraph pole 367/4; rail section (B. & O. bench mark 194)	649.520
Moundsville, 1 mile southeast of; a square cut in southwest end of northwest abutment of bridge 148 (B. & O. bench mark 195, U. S. G. S. bench mark)	646.508

CLARINGTON QUADRANGLE.

Moundsville north along Baltimore & Ohio R. R. to Benwood.

Moundsville, 0.2 mile northwest of, on north pedestal of water tank 54; square cut (B. & O. bench mark 196)	645.835
Moundsville, 1.4 miles northwest of, southwest of tracks at milepost 370; rail section (B & O. bench mark 197)	668.201
Moundsville, 2.4 miles northwest of, west of tracks at milepost 371; rail section (B. & O. bench mark 198)	667.586
Moundsville, 3.5 miles north of, in east end of coping of arch over spring at telegraph pole 371/39; copper bolt (B. & O. bench mark 199)	669.393
Benwood Junction, 2 miles south of, between main track and siding at milepost 373; rail section (B. & O. bench mark 200)	658.519
Benwood Junction, 1.5 miles south of, in large arch culvert at telegraph pole 373/20; copper bolt (B. & O. bench mark 200A)	657.952
Benwood Junction, 1 mile south of, at milepost 374; section of rail set vertically in ground between tracks (B. & O. bench mark 201)	665.538

WHEELING QUADRANGLE.

Bench marks near Benwood.

Benwood Junction, near, at milepost 375; section of rail set vertically in ground between tracks (B. & O. bench mark 202)	668.729
Benwood near, on west end of north coping at east end of east approach to Ohio River bridge; square cut (B. & O. bench mark 114)	688.195
Benwood, 9.5 feet north of southeast angle of pier of Baltimore & Ohio R. R. bridge over Ohio River, about level with Ohio River railroad track; cut on east face of West Virginia shore pier (United States Corps of Engineers bench mark 94A)	648.034

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 478

GEOLOGY AND ORE DEPOSITS NEAR LAKE CITY, COLORADO

BY

JOHN DUER IRVING

AND

HOWLAND BANCROFT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1911

CONTENTS.

ILLUSTRATIONS.

INSERT.

GEOLOGY AND ORE DEPOSITS NEAR LAKE CITY, COLO.

By John Duer Irving and Howland Bancroft.

FIELD WORK.

The field work on which this report is based was begun by the United States Geological Survey in the summer of 1904. During August of that year J. D. Irving spent a month in the district examining the properties then accessible and collecting notes and specimens for study. In the summer of 1908 new developments in the region made another examination expedient, and Howland Bancroft was sent to collect additional information and to bring Mr. Irving's observations up to date.

The mines have been worked for a long time and in a desultory manner and many of them have been abandoned, so that only a small part of the ore bodies that have been worked can now be examined. The data collected are thus necessarily fragmentary and the writers' generalizations are the result of field work done under somewhat difficult and unsatisfactory conditions.

This report is written jointly by Mr. Irving and Mr. Bancroft and is based both on the original field observations and the later observations and collections. For the chapter on the geology of the region the authors are indebted to Whitman Cross, who is also largely responsible for the geologic map.

ACKNOWLEDGMENTS.

To the owners and operators of the mines in the Lake City district the cordial acknowledgment of the authors is extended for maps of workings, statistical data, opportunities to study cost sheets and assay results, and unreserved permission to enter and study all accessible underground workings.

The long and eventful history of this camp and the changes of personnel in the mining population consequent on the many alternating periods of depression and intense activity have made the collection of accurate historical information very difficult. The history of the district (pp. 12–14) has been compiled chiefly from notes furnished by Mr. J. J. Abbot, who has been long and intimately associated

with the region and whose courteous aid is highly appreciated by the writers. These notes would be inserted in full as a section by Mr. Abbot if the limitations of space permitted.

GEOGRAPHY.

LOCATION AND GENERAL FEATURES.

The Lake City quadrangle is in southwestern Colorado, between longitude 107° 15′ and 107° 30′ W., and latitude 38° and 38° 15′ N., adjoining the Ouray quadrangle on the west. (See fig. 1.) It covers about 235.7 square miles and contains some of the most rugged

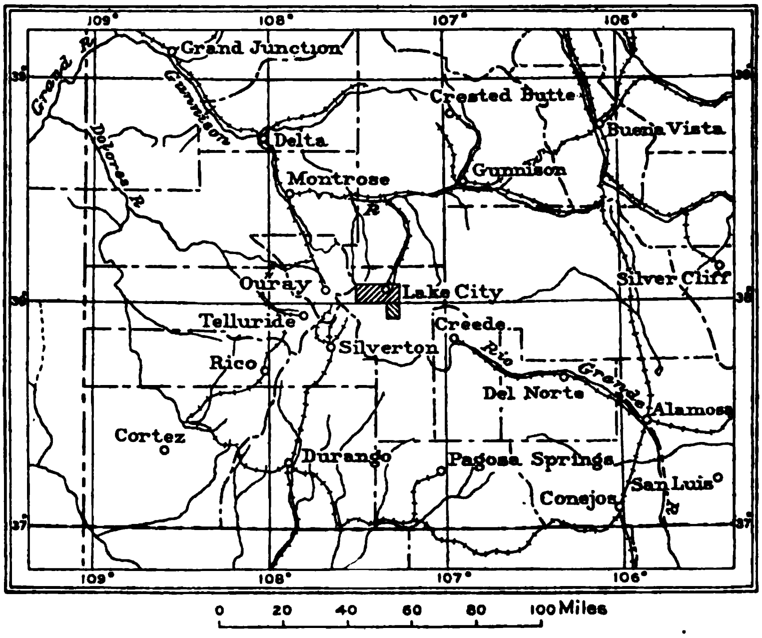
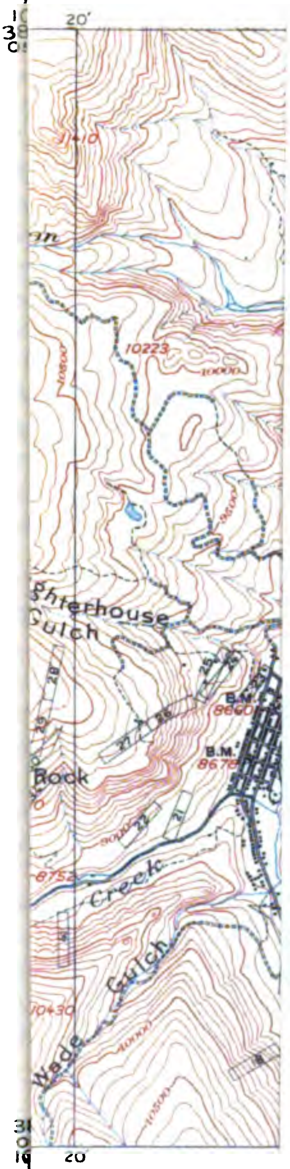


FIGURE 1.—Index map of a portion of Colorado, showing the location of the mining region discussed in this report.

mountains in Colorado, the most notable probably being Uncompahgre Peak, which stands 14,306 feet above sea level.

Lake City, a view of which is shown on Plate II (p. 12), is in the heart of the San Juan Mountains, in the northern part of Hinsdale County, at the junction of Lake Fork, a southern tributary of Gunnison River, and Henson Creek, which flows into Lake Fork from the west. The town is 8,663 feet above sea level, nearly the lowest point in the mining region here discussed. The ore deposits described are scattered along Henson Creek, to the west of Lake City, for about 10 miles and to the south, along Lake Fork and the western shores of Lake San Cristobal, for about 3 miles. The main region studied embraces an area of about 78 square miles, extending from latitude



QUADRANGLE

4 Miles

meters

38° to 38° 5′ N., and from longitude 107° 15′ to 107° 30′ W. To this is added about 3 square miles in the vicinity of Lake San Cristobal and about its shores. The location of these areas is shown in the index map forming figure 1 and in detail in Plates I and III and figure 20.

The region may be reached most conveniently through the valley of Lake Fork. Before the advent of the railroad a wagon road along Lake Fork served as the principal means of access, and the active development of the district from 1871 to 1889 was possible only under the stimulus of the discovery of rich ores. From other directions Lake City is accessible by wagon road from Creede and Silverton, and by a steep and rather hazardous trail from Ouray, on the west.

A branch of the Denver & Rio Grande Railroad from Lake Junction, 36 miles north of Lake City, now connects the town with the main narrow-gage line. From Lake City good wagon roads or trails lead to the principal mines; supplies are hauled as far as possible by teams and are then transferred to pack trains.

TOPOGRAPHY.

The surface of the region is composed principally of igneous rocks, which, under the action of streams, glaciers, and atmospheric agencies, have been wrought into a topography that is notable for its extreme roughness and irregularity. Viewing the country from Uncompahgre Peak, one is impressed by the approximate uniformity in the heights of the many high peaks of the San Juan Mountains and is led to conclude that these summits represent a formerly existing plateau which has been dissected by deep erosion.

The average difference in elevation between the stream beds and the ridges separating them is about 2,000 feet, but in some places the divide between two forks of the same small stream rises to heights of 3,000 feet or more above the bottom of the gulch. The lowest altitude in the quadrangle is slightly over 8,000 feet above sea level, and the elevation of Uncompahgre Peak, not over 12 miles distant, is 14,306 feet.

The region is in general drained toward the north, but the principal mining area is traversed by an eastward-flowing stream called Henson Creek, which, in the lower part of its course, runs through a deep, picturesque canyon. (See Pl. II, p. 12.)

OFFICIAL MINING DISTRICTS.

Hinsdale County is divided into mining districts, which here, as in other mining regions, have somewhat indefinite boundaries. As outlined by the legislative act of 1893, this part of Hinsdale County contains two districts, the Galena and the Lake. The Galena district, named from the presence of considerable quantities of the mineral of that name in the earlier exploited ores, extends westward along Henson Creek from Lake City to the Ouray and San Juan County lines. The Lake district, so called from its proximity to Lake San Cristobal, embraces the north and east portions of Hinsdale County. It extends southward from Lake City and westward along the valley of Lake Fork, including such prominent mines as the Golden Fleece, Black Crook, Isolde, and others in the section known as Burrows Park.

CLIMATE.

The effect of climate on the mining industry is fully appreciated by those who are engaged in mining operations in this region. In winter the streams are frozen and most of the mines are forced to use steam or gasoline engines instead of water power. The extra expense is great. Snow is so deep from December to April that operators of mines near timber line have to lay in supplies for the winter or cease work until spring.

TIMBER.

The timber in this region is all spruce or aspen, much of it available for use in the mines. The laws regarding the use and purchase of timber on mining claims, forest reserves, etc., are contained in brief in the "Use book" published by the Forest Service of the Department of Agriculture.

"Dry rot" of mine timbers is said to be a little more prevalent in the mines of the Lake City region than in most of the other mining districts in the vicinity. It is possibly due to the use of green timber in many of the workings; to insufficient circulation of air; to moisture in the shafts, adits, stopes, etc., sufficient to propagate fungous growth and not enough water to wash it away; and to the total neglect to use preservatives. The remedies for these evils are self-evident. If a few inexpensive precautions were taken, accidents to mine workings would greatly decrease. Circular No. 111 of the Forest Service gives a good brief account of methods of prolonging the life of mine timbers.

HISTORY.[1]

The history of the Lake City mining region is one of alternations—of general depression and of excessive activity—which have rendered its existence a little more eventful than that of the neighboring towns in the San Juan Mountains. These alternations have been due to several causes, but chiefly to the extreme richness of a few of the ore bodies discovered and the poverty of the rest. The periodical discoveries of new ore bodies of promising appearance were immediately followed by great inrushes of all sorts of people, whose presence

[1] Based mainly on notes furnished by Mr. J. J. Abbot, some of which are quoted directly.

A. VIEW OF LAKE CITY, COLO.

Photograph by Whitman Cross.

B. VIEW OF NORTH SIDE OF HENSON CREEK.

Photograph by Whitman Cross.

made the country thrive for a time. Similar variant conditions have prevailed to a greater or less extent in almost all mining centers, but in few places in Colorado have they been so pronounced as at Lake City.

Precious metal was probably first discovered in the Lake City area about 1842 by a member of the Fremont party, but no one, not even the explorer, has been able to locate the place or even the stream from which the first small amount of gold was panned. On August 27, 1871, with the discovery of the Ute and Ulay veins by Harry Henson, Jorl K. Mullin, Albert Meade, and Charles Godwin, the history of Lake City began. At that time all of the land which is now the "San Juan" belonged to the Indians. The reports of mineral wealth brought many prospectors into the region, and the red men became very much irritated at the frequent encroachments upon their domain. Finally, in 1874, to avert open hostilities, a treaty was drawn up and ratified by the Senate, whereby a strip of land 60 miles wide and 75 miles long was ceded to the United States Government by the Ute Indians.

In August, 1874, Hotchkiss (the leader of the expedition that built a wagon road from Saguache to Lake City) discovered the rich vein now known as the Golden Fleece and named it the "Hotchkiss." News of the strike spread rapidly and Lake City soon became a center of activity, the county seat being removed from San Juan to Lake City, where it has remained. During the same year reduction works were erected at Lake City and a third stamp mill was built in the Summit mining district.

Development was continued and new discoveries were made almost daily. The first boom attained its climax in 1876, coinciding with the opening up of Ocean Wave Group and the continued production of the Hotchkiss and the Ute and Ulay mines. During the spring the erection of a concentrator was begun and ground was broken for a smelter at the falls just above the city. Soon afterwards the reaction and "lull" so characteristic of the region began.

During the next three years work was continued on the Ute and Ulay and the Ocean Wave properties, the Excelsior mine was located (April, 1878), and the Crook and Ocean Wave smelters were completed.

The year 1880 marked the beginning of the biggest boom in the Lake City region. A great deal of work was done on the Palmetto group, which lies just west of the Lake City quadrangle. The St. Louis, Capitol, Czar, Silver Chord, Young America, Yellow Medicine, Pride of America, Vermont, Red Rover, and many other properties near Capitol City were being worked with various results.

Probably the most talked-of find during this period was that of the Golden Wonder, in Deadman Gulch, so named from four men who were killed and partly eaten there by their companion, Alfred Packer, in the winter of 1874.

This second boom period reached its climax near the close of 1881. In that year the Denver & Rio Grande Railroad, which had started to build to Lake City, became financially involved and ceased construction. In the fall of 1883 the Ute and Ulay shut down and for four years Lake City was practically dead.

In 1887 considerable ore was shipped from the Ulay, Vermont, and Yellow Medicine properties. The shipments from the Yellow Medicine mine fell off perceptibly in 1888, but the Ulay and Vermont continued to ship large quantities of ore. The Gallic was discovered during this period and later made a few shipments.

In 1889 the branch railroad was completed and soon afterward very rich ore was reported from the Golden Fleece. A single car of petzite ore from this mine is said to have yielded $50,000. The extreme richness of this ore stimulated mining throughout the region for about ten years. The total output of the Golden Fleece mine has been $1,400,000.

In 1890 some 20 mines in the Lake City quadrangle were shipping ore. During 1891 the Ute and Ulay alone produced over $400,000 and the total production from these mines has been $12,000,000.

In the late nineties the mining activity in the region almost reached a boom. Much work was done upon other properties in the vicinity of the Golden Fleece and some ore was shipped. The Golden Fleece Extension, Lake View, Black Crook, Contention, and others were operated. In June, 1897, the first ore was extracted by the present owners from the Hidden Treasure mine, as much as 22,000 tons of ore per year having been shipped from this property, which still continues to produce intermittently. The Czar first became a regular shipper in 1899, but its active life was short. The crest of the last wave of activity was reached during 1899, since which time operations have been more or less spasmodic.

PRODUCTION.

Hinsdale County originally included part of what is now Mineral County, in which the Creede mining district is located. On March 27, 1893, the legislature created Mineral County out of parts of Saguache, Rio Grande, and Hinsdale counties. For this reason statistics of production earlier than 1893 include also the production of Creede, which has been deducted in order to determine accurately the output of the present Hinsdale County, or practically the mining district here discussed. These statistics, except those for a few mines making confidential reports, have been compiled from the returns from individual mines as given in the reports of the Director of the Mint, in the reports of the State Bureau of Mines of Colorado, and, since 1904, in Mineral Resources of the United States, published by the United States Geological Survey.

The following table and figure 2 show the production of the county since 1884:

Metallic production of Hinsdale County from 1884 to 1906.

[Figures derived from United States Mint reports, 1884 to 1896, inclusive; from reports of State Bureau of Mines, Colorado, 1897 to 1903; from Mineral Resources of the United States, published by the United States Geological Survey, 1904 to 1908.]

Years.	Gold.	Silver.	Copper.	Lead.	Zinc.	Total value.
		Fine ounces.	*Pounds.*	*Pounds.*	*Pounds.*	
1884	$2,500	156,967	....	....	....	$180,317
1885	....	....	....	....	....	....
1886	2,060	18,586	....	30,435	....	23,743
1887	5,214	94,546	13,545	657,400	....	128,432
1888	2,667	110,433	1,815	1,495,614	....	172,586
1889	1,680	18,673	40,000	244,500	....	33,849
1890	3,577	61,023	40,950	546,920	....	96,112
1891	20,594	186,841	3,636	5,441,380	....	442,384
1892	13,529	418,422	20,182	6,225,747	....	653,107
1893	88,279	340,774	(a)	(a)	....	354,754
1894	95,293	404,750	(a)	(a)	....	350,286
1895	274,421	466,836	....	3,676,733	....	689,577
1896	215,648	465,598	13,006	6,934,099	....	725,668
1897	168,171	243,437	8,065	3,550,058	....	501,822
1898	51,282	186,456	104,038	9,828,482	....	529,151
1899	38,343	155,902	49,676	10,572,353	....	612,561
1900	56,470	155,485	29,180	9,377,062	....	600,309
1901	76,148	152,122	12,532	7,588,675	....	496,792
1902	98,348	117,177	8,314	6,213,763	....	428,733
1903	16,515	33,139	11,263	459,462	106,000	60,910
1904	7,692	39,283	10,530	1,054,421	75,815	81,416
1905	11,991	54,419	84,485	767,681	2,085	94,244
1906	24,510	87,940	63,261	753,950	30,475	140,543
1907	7,520	50,109	99,410	1,204,628	23,034	125,678
1908	2,454	29,498	188,698	280,465	....	54,776
Total	1,284,906	4,047,416	802,606	78,903,828	237,409	7,577,750

a No figures for lead and copper available.

No production is given for 1885 in the mint report, so the district was probably idle in that year. The production prior to 1884 can not be definitely determined, but as the Ute and Ulay mine was in active operation and the Ocean Wave and others were productive, it is probable that accurate statistics would show a yield nearly, if not quite, equal to that given in the table. This is the more likely as the years 1876 to 1881 marked the greatest boom that Lake City has ever experienced.

From these figures the curve in figure 2 showing the production of copper, lead, gold, and silver has been constructed. This curve shows clearly that the culminating years of the later history of the district were 1895 and 1896, in the latter of which the yield was nearly three-quarters of a million dollars. It shows the general rise, culmination, and decline of the district, and brings out clearly the alternate periods of activity and depression. In 1889 the production was less than $35,000, but the advent of the railroad into Lake City that year caused a rapid increase, culminating in 1892. In 1893 the financial depression, coupled with a gradual decline in the value of silver caused a sharp fall, followed by a rapid rise until 1896. The decrease

Certain mines indicated in this list were not studied, as they lie too far outside of the district examined to warrant field work, and they are not further mentioned in this report. Many of them, however, have contributed to the production of Hinsdale County.

Those marked with an asterisk are within the northeastern portion of the Silverton district and have been described by Ransome.[1]

The observed conditions 300 to 400 feet below the surface lead the writers to believe that only the roots of veins are present in the district and that all ore bodies are likely to diminish greatly in value in depth. Hence the life of any mine is likely to be brief. The change in character of the ore and gangue minerals with depth in the Ute and Ulay, Hidden Treasure, Black Crook, and numerous others illustrates this point remarkably well.

GEOLOGY.

By Whitman Cross.

The Lake City district is a small part of the volcanic San Juan region. Geologically it is particularly allied to the adjacent portion of the San Cristobal quadrangle on the south, which has been recently surveyed, and to the Silverton and Ouray quadrangles on the southwest and west, respectively, the geology of which has been described in published folios.[2] For this reason the geology of the San Juan region as a whole will first be briefly discussed, especially the important relations of the rock formations that occur in the Lake City area. Next the geology of the Lake City district itself will be described.

SAN JUAN MOUNTAINS.

GENERAL FEATURES.

The San Juan Mountains consist chiefly of surface volcanic rocks or of intrusive igneous masses, which now cover an irregular area of more than 3,000 square miles. This volcanic area extends from San Luis Park on the east to an irregular and abrupt western mountain front in the Telluride quadrangle. On the north the volcanic rocks reach out beyond the mountainous district proper, the lower lavas capping long low ridges between southerly tributaries of Gunnison River, in some of them extending to the edge of the Black Canyon. The southern border of the volcanic district runs from the Telluride quadrangle somewhat south of east and a broad arm crosses into New Mexico.

It is evident that the lavas once extended far beyond their present limits on all sides except the east. Between the San Juan and West

[1] Ransome, F. L., A report on the economic geology of the Silverton quadrangle, Colorado: Bull. U. S. Geol. Survey No. 182, 1901.

[2] Silverton folio (No. 120) and Ouray folio (No. 153), Geol. Atlas U. S.

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Elk mountains, which lie north of Gunnison River, there was once a continuous covering of volcanic rocks, but these rocks did not necessarily come from a single central source. The Hayden geologic map of Colorado is approximately correct in its representation of the limits of this volcanic area, but it fails to give any idea of the complexity of the lavas, either as to character or age. The eruptions occurred during nearly the whole of Tertiary time, when a great many different kinds of lavas were poured out, building up a huge volcanic plateau. Eruptive activity was not continuous during the Tertiary period, but was broken by long intervals of quiet, during which extensive erosion materially changed the topography of the volcanic pile.

In the survey of the San Juan region, which now covers more than its western half, it has been found desirable to map and to describe the rocks of the principal eruptive periods in groups or series rather than to emphasize the occurrence of special rock varieties, and this method will be followed herein.

THE EARLIEST ERUPTIONS.

The commencement of volcanic activity was clearly later than the deposition of the Upper Cretaceous coal measures of southwestern Colorado, but somewhat earlier than any of the recognized Tertiary formations of the region. This is shown by the Animas formation, which overlies the coal measures at Durango and which consists largely of the pebbles and gravel of andesitic volcanic rocks. These beds carry fossil plants and scanty vertebrate remains which prove them to be of the same age as the Denver formation, at the base of the Front Range—that is, early Eocene or uppermost Cretaceous. The source of the volcanic materials of the Animas formation is not yet known.

SAN JUAN TUFF.

The Animas formation does not extend into the San Juan Mountains proper, and the lowest or earliest member of the great volcanic complex found in the western part of the region is a fragmental deposit which has been called the San Juan tuff. It is a more or less plainly stratified series of tuffs, breccias, or coarse agglomerates of andesitic rocks, in which no fossils have been discovered. No lava flows have been found interbedded with the fragmental deposits.

The San Juan tuff has a maximum observed thickness of 3,000 feet and forms notable deposits in the Ouray and Telluride quadrangles, though it appears in all other surveyed areas on the border of the volcanic district. It occurs in typical form in the Cimarron and Blue Creek valleys of the Lake City quadrangle.

The source of the andesitic rocks of the San Juan tuff was a mystery previous to the survey of the Lake City quadrangle. It now appears

HINSDALE VOLCANIC SERIES.

The western San Juan region exhibits no lavas more recent than those of the Potosi volcanic series, but in portions of the San Cristobal and Uncompahgre quadrangles, and presumably in others not yet examined, a later succession of eruptions took place, producing a series of lavas differing notably from the products of earlier eruptions. It is plain that much erosion of the Potosi volcanic series occurred before the extrusion of these later magmas, which, so far as known, closed the long sequence of lavas in the San Juan region.

This newly recognized series of lavas ranges from a rhyolite very rich in quartz and alkali feldspar but poor in calcic feldspar and in all ferromagnesian minerals to a normal olivine plagioclase basalt. Between these two extremes are lavas of several types possessing some characteristics distinguishing them from earlier lavas.

No rocks of this recent series have been described in earlier folios or reports, and it is proposed to call them the Hinsdale volcanic series because of their important occurrences in Hinsdale County, of which Lake City is the county seat. The most extensive deposits of these lavas thus far discovered are on the divide between Lake Fork and Cebolla Creek, directly east of Lake City. The section exposed is nearly 1,200 feet thick. The lower 800 feet of the series occur within the area of the accompanying map on a spur from the divide. Other important localities for these rocks are Cannibal Plateau, northeast of Lake City; the Continental Divide, between Lake Fork and the head of Cebolla Creek; several summits between branches of Clear Creek; and the hill north of Lost Lake, the last three being in the San Cristobal quadrangle. All localities named are in Hinsdale County.

The Hinsdale is, like the Potosi and Silverton volcanic series, a set of lavas representing one of the major divisions of the San Juan volcanic history rather than a petrographic group. It is too early to sharply define its limits.

LAKE CITY DISTRICT.

GENERAL GEOLOGY.

Nearly all the rocks of the Lake City area (see Pl. III), belong to the Silverton volcanic series, the great intermediate member of the Tertiary volcanic complex. No earlier formation occurs here, and only subordinate representatives of the later Potosi and Hinsdale volcanic series occur in the district. Intrusive masses are numerous, but though these are obviously younger than the rocks which they penetrate their exact age relations are nowhere clear.

The canyon of Henson Creek, which is the most prominent topographic feature of the area, presents an excellent though by no means

A. ROUNDTOP MOUNTAIN, LAKE CITY MINING REGION.

Photograph by Whitman Cross.

B. POST-GLACIAL CANYON OF HENSON CREEK.

Showing gorge in Eureka rhyolite. Missouri Favorite Mine is in the center.

complete section of the prevailingly somber rocks of the Silverton series. On its southern side the lowest (oldest) member of the series, the Picayune group, predominates, and on its northern side several higher (younger) members are well shown. The general northerly dip of the lavas and tuffs affords proof that the center of eruption during the Silverton epoch of volcanic action was south of the Lake City area.

The restrictions of the map prevent representation of the fact that the various rocks of the Silverton series do not extend far northward beyond Henson Valley nor eastward beyond Lake Fork. This limitation is due to great erosion in the epoch preceding their eruption. The San Juan tuff and perhaps earlier massive volcanic rocks once existed where the Silverton lavas of Henson Creek now are. By their erosion a steep southward-facing slope or cliff was produced near the north boundary of the Lake City district. The Potosi rhyolites and latites cap the divide north of Henson Creek on either side of El Paso and Nellie Creek, resting on the uppermost rocks of the Silverton series; they are very prominent in the northern part of the Lake City quadrangle, forming plateau-like ridges with a gentle northerly dip. They are cut in the valleys of the east fork of the Cimarron, Blue Creek, Elk Creek, and other streams, exposing the underlying rocks; but these are not at all like the Silverton volcanic rocks of Henson Creek, consisting, instead, of a great volcanic breccia or semiconglomerate of rude bedding, which extends west into the Ouray quadrangle, where it is shown to be the San Juan tuff, a formation entirely older than the Silverton series. These relations of the San Juan tuff and the Silverton rocks are not clearly exposed in the Lake City quadrangle, but they are exhibited in the Ouray quadrangle and have been described and illustrated in the folio dealing with that area. The Potosi lavas, therefore, overlap the boundary between the San Juan tuff and the Silverton series.

Although the canyon of Henson Creek cuts so deeply into the Silverton volcanic series, it does not actually penetrate below it at any point within the Lake City quadrangle. There is, however, evidence that granite and very old quartzite rocks lie probably at no great distance beneath the Picayune lavas on Henson Creek.

That granite is one of the foundation rocks is indicated by a small exposure of that rock 2 miles southwest of Capitol City in the bed of a southerly branch of Henson Creek, which it enters east of the Moro mill. This granite is on the north side of a fault of undetermined throw and the exposure is but a few yards in diameter. It is but 1½ miles from this point south to the large fault block of granite, the great part of which lies north of Whitecross, at the head of the Lake Fork.

Quartzite resembling the pre-Cambrian rocks of the Uncompahgre Canyon at Ouray occurs in a small exposure, surrounded by volcanic rocks at an elevation of 11,800 feet, a little more than a mile southeast of Capitol City. The exposure is insufficient to show whether this quartzite is a large block included in the volcanics or a pinnacle of an underlying rugged quartzite topography, but it does make it clear that rocks other than granite go to make up the prevolcanic complex of this vicinity. At several places in the San Cristobal quadrangle chaotic breccia masses in the Picayune volcanic group contain fragments of granite and quartzite, some of which are several yards in diameter.

SILVERTON VOLCANIC SERIES.

PICAYUNE VOLCANIC GROUP.

Occurrence.—The rocks of the Picayune volcanic group, together with intrusive masses, occupy the greater part of the area between Henson Creek and the Lake Fork to the south. They occur connectedly in the Henson Valley from near Capitol City to a point below the mouth of Alpine Gulch and in separated areas in Wade Gulch, on the slope between Wade and Alpine gulches, and on the west side of the Lake Fork opposite Deadman Gulch. The rocks rise higher on the south side of Henson Creek than on the north, owing to a general northerly dip of their upper surface, on which the Eureka rhyolite rests.

The rocks of the group are prevailingly dark in tone and cause somber cliffs in which a rude stratified arrangement of successive flows or beds can be recognized in many places. Among the best exposures for a study of the Picayune rocks are the steep cliffs at several points between El Paso and Modoc gulches, and in Wade Gulch near the quadrangle line. There is much landslide and forest cover on the south side of Henson Creek, although the rocks are well exposed in many localities.

General character.—The lavas and fragmental rocks here called the Picayune volcanic group once formed a great volcano, the center of which was situated a few miles south of Henson Creek, in the area between that stream and the upper part of Lake Fork. The rocks of the group are principally dark andesites, dacites, and quartz latites, with a variable amount of light-gray rhyolite. The petrographic distinctness and the sharp local boundaries of certain masses made it at first appear practicable and desirable to distinguish them on the map, and much time has been spent trying to do this. But with greater knowledge of this old volcano it has become clear that a petrographic division of the group can be mapped only at some future time, after long and painstaking study and with a topographic base of much detail and great accuracy. The lavas, tuffs, and breccias of the group are therefore mapped collectively under one color, and only the more important and definite intrusive rocks are distinguished.

The structure of the Picayune mass is most irregular. A large part of it is breccia—that is, it is made up of angular rock fragments. Some breccias are composed almost exclusively of one kind of rock and appear to have been made by the shattering of massive rock in place. Other breccias are simply chaotic accumulations of several different rock types, in large and small fragments. Well-bedded deposits of more or less worn, transported material also appear but are not continuous enough to express a prevalent structure.

Lava flows alternate with breccias or tuffs in many local sections, but these, too, possess little lateral extent. Intrusive masses of various shapes and sizes, consisting of rock varieties for the most part identical with some of the flows or breccia fragments, are, by reason of the prevalent irregularity of all masses, distinguishable only with the greatest difficulty and in favorable localities.

No regular succession of magmas of different character has been made out. Probably the oldest lavas of the Picayune center were andesitic and the later ones chiefly rhyolitic or latitic. Such appears to be the general rule, but apparent exceptions are numerous.

The Picayune rocks are more extensively altered than the younger lavas. This is quite natural in view of the fragmental character of much of the mass and the local extent of even the largest massive bodies. These conditions must have been favorable to the free circulation of solvent and mineralizing waters.

Typical exposures.—The development of the Picayune volcanic group in the Henson Valley may be best described by giving details of typical localities. One of these is the ridge between Nellie and Pole creeks, on the southeast face of which the Picayune rocks are exposed for about 1,500 feet, above the mouth of Nellie Creek. A well-stratified conglomerate and breccia, forming ledge exposures by the roadside at several places between Pole and Modoc creeks, is the base of the exposed section. This stratified rock appears at first to have nothing to do with the darker volcanic complex about it, but it is, in fact, only a phase of the rhyolitic tuffs or conglomerates found in local development in many places, at various horizons. The conglomerate is overlain by a coarsely stratified breccia, dipping 25° to 30° N. Adjacent outcrops are similar for the most part but differ in relative proportions of rock types and in texture. At about 200 feet above Henson Creek a brecciated nearly homogeneous rock is overlain by a flow, the lower zone of which is marked by fluidal structure. This extends for about 100 feet vertically, the dense dark rock being almost homogeneous though more or less brecciated. At an elevation of 300 feet a finely bedded sandy tuff occurs with a flow only 5 to 6 feet thick in its midst. This flow has sharp contacts and fluidal border zones. A variable dip reaching 30° N. as a maximum is here distinct. Above these gray tuffs comes another much thicker flow similar to the one in the tuffs. Breccia and irregular masses of more basic rocks follow, with gray latite or rhyolite at certain horizons, and this alternation continues up to the massive Eureka rhyolite flow.

The Picayune rocks east and north of Capitol City deserve particular mention, for their relations to the Eureka rhyolite are not fully understood. The heavy coating of glacial débris on North Fork of Henson Creek obscures the geology very much, but the Lucky Strike tunnel, at Capitol City, penetrates greenish quartz-bearing andesite, quartz monzonite porphyry, and rhyolite similar to the Eureka type, the whole indicating a complex phase of the Picayune group.

The same rocks and other types known in the Picayune are found in Yellowstone Gulch and are encountered in the Gallic tunnel. In the latter locality Eureka rhyolite occurs on the slope above the tunnel and is the only rock observed along the banks of North Fork of Henson Creek, as far as Capitol City. These facts show that an arm of the Picayune group rocks extends up North Fork, rising much higher on the northeast side.

The rock referred to as quartz monzonite porphyry is no doubt an intrusive, identical in composition with the body represented on the map as penetrating Eureka rhyolite on the slope west of Capitol City. It is not improbable that the coarse quartz monzonite porphyry of the Gallic tunnel, Yellowstone Gulch, the Excelsior mine, and the Lucky Strike workings, as well as of certain outcrops surrounded by glacial material southeast of Capitol City, is of the same age as the body in Eureka rhyolite. But the boundaries can not be determined and so it can not be separated from the Picayune.

East of Capitol City and north of Henson Creek the line between Eureka rhyolite and the Picayune volcanic group has not been accurately determined and hence no definite boundary is shown on the map.

Some of the later rhyolite flows of the Picayune epoch were very much like the succeeding Eureka rhyolite and they do not seem to be so much broken as earlier lavas, so that it is difficult to determine whether the rhyolite of some areas south of Henson Creek should be referred to the Eureka or not. A massive gray rhyolite on the ridge west of Alpine Gulch closely resembles the Eureka, but it dips beneath dark andesitic rocks near the mouth of the gulch and is for this reason included in the Picayune.

EUREKA RHYOLITE.

The Eureka rhyolite in a succession of flows covers the Picayune volcanic group on the north side of Henson Creek and extends up the south slopes east of Alpine Gulch and near Capitol City. The character of the rock is well shown in the canyon of Henson Creek

(Pl. IV, *B*) for 2½ miles above Lake City and in the cliffs west of the town. It is also present east of the town on the lower slopes.

The Eureka rhyolite is typically a dull ash-gray or green felsitic rock with few phenocrysts that exhibits a pronounced fluidal texture as seen in exposures a few feet in diameter if not in hand specimens. Feldspar and biotite crystals give the rock a porphyritic facies, as a rule, the groundmass strongly predominating in most places. Inclusions of rock fragments very similar to the Eureka are common in most flows and suggest the term flow breccia. These fragments are usually but a fraction of an inch in diameter and they are commonly rather flat flakes arranged in bands, emphasizing the fluidal structure.

Some of the Eureka rhyolite flows are several hundred feet in thickness and their lateral extent is measured by miles. A small amount of tuff separates some of the flows, but more commonly these are in direct contact and are so similar that the boundaries are often not easily detected.

As has been pointed out (p. 20), the Eureka lavas are practically identical in character with some of those in the Picayune group. The justification for distinguishing the Eureka as a map unit lies in its mass and areal importance. The lava floods of Eureka time covered a large part if not all of the complex Picayune volcanic group.

BURNS LATITE TUFF.

The Burns latite tuff division of the Silverton volcanic series is represented in the valley of Henson Creek only by fine-grained sandy tuffs and calcareous beds, which extend northeast from the south base of Sunshine Mountain to the ridge west of Nellie Creek and beyond the area mapped. Near Nellie Creek the tuffs rest on Eureka rhyolite, in their normal relation, but in El Paso Gulch, Empire Mountain, and North Fork of Henson Creek they are separated from the rhyolite by intrusive sheets of pyroxene andesite. The tuff band varies greatly in thickness, owing to erosion before it was covered by andesite flows; northwest of Yellowstone Gulch it wedges out entirely.

In the drainage areas of Modoc, Findley, and Crystal creeks the Burns latite tuff is concealed by flows of the Potosi volcanic series, but it reappears west of Crystal Peak and occupies a considerable area between Slaughterhouse Gulch and Larson Creek. It is, however, much obscured by landslide material consisting largely of gray-green Burns tuff, which extends to Lake Fork immediately below Lake City.

The tuff reappears east of Lake City, lying on the Eureka rhyolite, and continues southward across Deadman Gulch, being interrupted by glacial débris and penetrated by several intrusive rocks.

The Burns tuffs are mainly fine-grained gray or greenish sandstones, made up chiefly of particles of volcanic rocks. Some beds include rock fragments several inches in diameter. Other layers are thin laminated shale. Certain layers of some exposures are rich in carbonate of lime, and true limestone strata 2 or 3 inches thick are locally developed. These calcareous beds are well exposed on the flat summit of the ridge east of El Paso Gulch. A few fossil leaves have been found in the Burns tuff in the ravine north of North Fork of Henson Creek, and fragments of carbonized plant stems are common.

PYROXENE ANDESITE.

Dark massive flows of pyroxene andesite normally succeed the Burns tuff in the Silverton volcanic series. Such rocks reach a thickness of several thousand feet in the Silverton quadrangle, but they do not exceed 800 feet in the valley of North Fork of Henson Creek and gradually thin out eastward. They have not been found east of Nellie Creek. These andesites occur in flows varying from a few feet to more than 100 feet in thickness.

Below the Burns tuff occur nearly identical sheets of rock, which have not been distinguished on the map. In several places it is clear that these lower bodies have been intruded, and they no doubt belong to the same epoch of eruption as the flows above the tuffs. In El Paso Gulch and the ridge east of it the evidence of intrusion is plain and is expressed in part on the geologic map.

The pyroxene andesites are dark porphyritic rocks, with numerous crystals of augite and plagioclase visible to the unaided eye. They are massive except in the upper zones of most flows, where a pronounced vesicular texture is commonly developed. Secondary quartz and bluish chalcedony are usually found in these vesicles and, as they readily weather out of the rock in exposed places, small nodules or fragments of them strew the ground in many places near outcrops.

The microscope shows that hypersthene was a former constituent of these rocks, its place being now taken by serpentine, chlorite, and other alteration products. Quartz and orthoclase are generally present in small amount.

HENSON TUFF.

The last member of the Silverton volcanic series is a tuff much like the Burns latite tuff. Its greatest development is in the valley of North Fork of Henson Creek in the Ouray quadrangle. It lies on the pyroxene andesites in the region west of Nellie Creek, but is not found east of that stream.

The Henson tuff is made up chiefly of débris of pyroxene andesite, but contains particles of other volcanic rocks; locally it contains angular fragments of rhyolite, latite, and andesite. There are no calcareous layers in it, like those of the Burns tuff, and no fossil leaves have been discovered.

POTOSI VOLCANIC SERIES.

The lavas of the Potosi volcanic series appear in the Lake City area only on the high ridges on either side of Henson Creek and east of the Lake Fork. They lie on various older formations, in some places with unconformity, testifying to much erosion following the deposition of the Henson tuff.

North of Yellowstone Gulch the Potosi lavas rest on Henson tuff or an intrusive quartz latite sheet, and in Empire Mountain they lie on pyroxene andesite and Burns latite tuff. On either side of Crystal Creek the Eureka rhyolite is the underlying formation, and east of Alpine Gulch the Potosi lavas come in contact with the Picayune rocks.

The Potosi lavas of the region north of Henson Creek are light or dark gray quartz latites exhibiting many soda-rich plagioclase feldspar phenocrysts and some of sanidine in a groundmass rich in quartz and sanidine. Biotite and augite are original constituents, but are generally quite decomposed.

The alteration of Potosi rocks by which they are silicified or kaolinized is extreme in the so-called "Iron beds" northwest of Broken Hill. Much of the rock is stained a brilliant red or yellow through oxidation of the pyrite which impregnated it at the time of its decomposition. Alteration of this type is also exhibited in less degree south of Broken Hill.

The Potosi rocks east of Alpine and Wade gulches are quartz latite porphyry belonging to a large body which apparently filled a great hollow. This rock is characterized by more prominent crystals both of plagioclase and sanidine feldspar than are found in the common thinner flows north of Henson Creek. The upper parts of Crown Mountain and Red Mountain in the San Cristobal quadrangle are made up of this same phase of the Potosi quartz latite.

The Potosi lavas east of Lake City are mainly dark pyroxene andesite of a type common to the southeast. North of Horse Park they are representatives of quartz latite flows beneath the andesites.

HINSDALE VOLCANIC SERIES.

The lavas of the Hinsdale volcanic series overlie the Potosi flows east of Horse Park. They belong to the succession of rhyolite, basalt, and intermediate rocks forming the upper portions of the divide between Lake Fork and Cebolla Creek. The basalts are the capping rocks of Cannibal Plateau and are recognized as such in the Hayden reports and on the map. These rocks have not as yet been thoroughly examined, and as they are supposed to be more recent than the ore deposits of the Lake City region they need no further discussion in this place.

INTRUSIVE ROCKS.

The intrusive rocks of the region are distinguished on the map under three colors. These rocks are not intimately related to the ore deposits and will be passed over in this place with but brief mention. Some of the types occur in more important masses in the areas north or south of that with which this report deals and will be described in full in forthcoming reports. The various kinds of intrusives may be conveniently grouped under the heads of the map legend.

Rhyolite.—The most widely distributed type in this group is a rhyolite which is very abundant south of Henson Creek in bodies of various sizes and shapes, cutting the Picayune volcanic group. To the south, as far as the Lake Fork, in the San Cristobal quadrangle, this rhyolite is very abundant throughout the area of Picayune rocks and makes up a large part of some of the highest summits, such as Red Cloud and Sunshine peaks. It includes many large blocks of the Picayune lavas, a few of which are represented on the accompanying map.

This rhyolite is a grayish porphyry exhibiting phenocrysts or orthoclase, and quartz with a few biotite flakes, in a felsitic groundmass. In some places the rock has a strongly marked fluidal texture and in others it is massive. Inclusions similar to those in the Eureka rhyolite are abundant in some localities. The groundmass is very fine grained in places but is never glassy. A gradation to coarse-grained texture takes place in certain masses, so that some of the rock may well be called granite porphyry. Masses of such texture occur principally in Alpine Gulch, in the San Cristobal quadrangle.

This rhyolite differs markedly from the Eureka rhyolite in the constant presence of quartz phenocrysts penetrated by many white arms or embayments of the groundmass. It is also more typically a rhyolite than is the Eureka, being generally free or nearly so from crystals of lime-soda feldspar.

A rhyolite porphyry characterized by numerous phenocrysts of smoky quartz and clear sanidine, but almost destitute of any ferromagnesian mineral, occurs in many crosscutting dikes and irregular bodies in the drainage areas of Nellie and El Paso creeks and the North Fork of Henson Creek. Several small masses of this rock are represented on the map. This rhyolite penetrates flows of the Potosi volcanic series and is probably much younger than the similar rock in the Picayune area, already referred to.

A rhyolite of felsitic type forms the summit of the hill east of Lake City, which stands at an elevation of 10,726 feet. It is fine-grained, gray, or pinkish in color, and has a fluidal texture due to the arrangement of spherulitic bands. A smaller mass occurs in the knoll north of Deadman Gulch and seems to be intrusive, though surrounded largely by glacial gravels.

The intrusive mass west of Crystal Creek opposite Sugarloaf Rock is a rhyolite resembling the Eureka rhyolite in many particulars.

Quartz latite.—In the hill east of Lake City and in Deadman Gulch are several sheets of a fine-grained quartz latite, which cut the Burns latite tuff irregularly. This rock is gray in color, with small crystals of plagioclase, sanidine, biotite, and quartz in a subordinate groundmass. The quartz crystals are embayed by tongues of the groundmass, after the fashion of the rhyolite south of Henson Creek, but the rock contains much plagioclase, is rich in biotite, and carries a little hornblende. It is called quartz latite porphyry.

Another rock of this kind, nearly identical in character with certain flows of the Potosi volcanic series, occurs as a sheet or sill injected above, below, or within the Henson tuff, in the area between North Fork of Henson Creek and Nellie Creek. In some places it is 200 to 300 feet thick. It extends north 2 miles from Broken Hill, reappearing at the head of Cimarron Creek, southwest of Uncompahgre Peak.

This rock is gray, with prominent biotite crystals, and is more compact than the usual Potosi flows, but it shows fluidal texture in some places and may represent an intrusion during the Potosi epoch of a magma which reached the surface elsewhere in the vicinity.

The quartz latite forming the summit of Sugarloaf Rock is a fine-grained porphyry different from any of the preceding types. It contains both hornblende and biotite phenocrysts, while quartz is restricted to the groundmass.

Andesite.—A sheet of dark fine-grained andesite cuts obliquely across the Burns latite tuff in the face of the hill east of Lake City. The rock carries hornblende in abundance, with some augite and biotite, all greatly altered. No other mass of this character occurs in the area described in this bulletin.

Quartz monzonite porphyry.—In the ridge west of Capitol City there occurs a branching intrusive body of much more coarsely crystalline texture than is exhibited by any other intrusive distinguished on the map. It cuts the Eureka rhyolite and is probably more extensive than is indicated by the map, for landslide and glacial débris obscure its outcrops very greatly.

This rock contains many prominent hexagonal tablets of biotite, associated with plagioclase and some quartz phenocrysts. The groundmass is rich in orthoclase and quartz of microgranular texture. Rock of nearly identical character occurs in the breast of the Gallic tunnel, according to Bancroft, and in all probability this mass is connected beneath the surface with the body mapped.

Decomposed porphyry of Deadman Gulch.—The highly decomposed rock occurring in Deadman Gulch and extending into the adjacent valley on the south is in part a porphyry with little remaining of its original constituents except quartz phenocrysts with penetrating arms of the groundmass. This suggests that there may be here intrusive bodies of quartz latite or rhyolite porphyry similar to some one of the types described, but in a large part of the area the rock is so completely silicified or kaolinized that the primary characters have wholly disappeared. Since to these obscuring effects of decomposition are added the covering of all but the upper contacts by glacial or landslide detritus, it has been impossible to determine the original character of the rock or even to decide whether or not more than one rock type is represented.

This area of alteration is directly connected with that at the head of the great Slumgullion mud flow which dammed the Lake Fork and caused Lake San Cristobal. The extreme head of that flow is very near the southeast corner of the Lake City quadrangle. The alteration in Deadman Gulch is not quite so thorough as in the Slumgullion Basin, but disintegration of the decomposed rock is a common feature of prospect dumps in the former area.

The decomposition in question extends upward with diminished intensity into the lavas of the Potosi volcanic series, but apparently the massive flows of andesite served to confine the decomposing waters in some degree and thus promote the alteration of underlying rocks.

ORE DEPOSITS.

SAN JUAN REGION.

GEOGRAPHIC CONTINUITY.

The Lake City area is not an isolated locality whose general relations may be discussed without reference to those of adjacent regions. On the west is the Ouray region; on the southwest the famous and productive Silverton and Telluride regions; and still farther southwest are the well-known camp of Rico and the lesser districts of the La Plata and Needle Mountains quadrangles. These six mining regions together make up the major part of the famous San Juan mining region and form one connected mountainous district characterized throughout by extremely rugged topography, a preponderance of extrusive and intrusive eruptive rocks, and an extensive and more or less closely related mineralization. The Lake City district is situated on the northern border of this region and is separated from the Creede district to the southeast by a considerable tract of country in which no ore bodies of consequence have yet been discovered. The veins differ from those of the Telluride, Ouray, and much of the

Silverton region in being in an older series of volcanic rocks; the San Juan tuff, which is so abundantly mineralized in the latter quadrangles, does not outcrop within the mineralized part of the Lake City area. The region is geologically continuous, however, with the eastern and central portions of the Silverton quadrangle, a great part of the rocks there exposed belonging to the same groups as those in the vicinity of Lake City. The veins show many close similarities, both physically and mineralogically, to those in the adjoining portion of the Silverton area; and it is highly probable that they owe their origin to similar conditions of mineralization, fissure formation, etc.[1]

GENESIS OF MINERALS IN THE SAN JUAN REGION.

It has for some time been recognized that different associations of minerals form under different conditions of temperature and pressure. Those formed under high temperature and pressure are in extreme instances entirely different from those formed under low temperature and pressure, and the mineral formation may be regarded as a measure of the vertical depth at which ore formation has occurred; that is to say, the earth's crust in any given locality may be divided into zones of depth, and within the vertical range of each zone characteristic temperature and pressure may be assumed to have existed. The mineral contents of the veins of any region will then express in some degree the depth at which the minerals formed. In 1907 Lindgren[2] pointed out the existence of certain zones and set forth the minerals characteristic of each of them. In 1908 W. H. Emmons[3] followed with a paper giving a tentative genetic classification of minerals, amplifying the work of Lindgren.

In comparing the different districts of the San Juan Mountains with the Lake City district the writers have endeavored, by the use of this work of Lindgren and Emmons together with their own additions and observations, to classify the minerals constituting the ore deposits of the five districts above mentioned into groups, each of which is characteristic of a particular zone.[4] Six such groups were found to exist, as follows: (1) Minerals of the oxidized zone, (2) minerals due to secondary sulphide enrichment, (3) minerals formed at moderate and shallow depth, (4) contact metamorphic minerals, (5) minerals of the deep-vein zone, (6) minerals which may occur in all or most zones and are of no diagnostic value.

[1] Ransome, F. L., A report on the economic geology of the Silverton quadrangle, Colorado: Bull. U. S. Geol. Survey No. 182, 1901.

[2] Lindgren, W. L., The relation of ore-deposition to physical conditions: Congr. geol. intern., Compt. rend. 10^e sess., Mexico, 1906, pp. 701-724, 1907; Econ. Geology, vol. 2, No. 2, pp. 105-127, 1907.

[3] Emmons, W. H., A genetic classification of minerals: Econ. Geology, vol. 3, No. 7, pp. 611-627, 1908.

[4] See tables, pp. 34 and 46, compiled to show the comparative mineralogy of the San Juan and the primary mineralogy of the Lake City region.

The first two groups belong to surficial zones and afford no true basis of genetic comparison, as they may be superposed on any series of deposits, of whatever origin, which contain sulphides and other elements in necessary amount. Differences in them afford comparison only of varying topographic and climatic conditions. As such conditions vary but little in the San Juan region, the secondary and oxidation products show a striking similarity throughout. The third, fourth, and fifth groups furnish a good basis for a comparison of the primary minerals. The details of their occurrence (see table below) in the various districts of the San Juan region, though accurate only within the limits of our present knowledge, yield some significant results, which in the writers' opinion, serve to emphasize the close relation of the Lake City region and the other areas and to bring out such differences as exist.

TABLE 1.—*Comparative mineralogy of the San Juan region.*

	Lake City.	Ouray.	Silverton.	Telluride.	Rico.
1. Minerals of oxidized zone	...	Basic ferric sulphate.	...	...	Oxidized products not specifically enumerated.
	Kaolinite	Kaolinite	Kaolinite	Kaolinite	
	Limonite	Limonite	Limonite	Limonite	
	Hematite	Hematite	Hematite	Hematite	
	Native silver	Native silver	Native silver	...	
	Gold	Gold	Gold (?)	Gold	
	Copper	...	Copper	Native copper	
	Malachite	Malachite	Malachite	Malachite	
	Azurite	Azurite	Azurite	Azurite	
	Cerussite	Cerussite	Cerussite	Cerussite	
	Anglesite	...	Anglesite	Anglesite	
	Chalcanthite	...	...	Chalcanthite	
	Pyrolusite	Gypsum	...	Gypsum	
2. Minerals produced by secondary sulphide enrichment	Covellite	...	...	...	
	Chalcocite	Chalcocite	Chalcocite	...	
	Bornite	...	Bornite	...	
	Galena	...	...	...	
	Proustite	Proustite	Proustite	Proustite	Proustite.
	Pyrargyrite	Pyrargyrite	...	Pyrargyrite	
	Argentite	...	Argentite	...	Argentite.
	...	...	Stromeyerite	Stephanite	Stephanite.
	...	...	...	Polybasite	Polybasite.
3. Minerals of moderate and shallow depths.	Sericite	Sericite	Sericite	Sericite	
	Hinsdalite	...	Hinsdalite	...	
	Jasperoid	Jasperoid	Jasperoid	Jasperoid	Jasperoid.
	Barite	Barite	Barite	Barite	Barite (rare).
	Rhodochrosite	Rhodochrosite	Rhodochrosite	Rhodochrosite	Rhodochrosite.
	...	Rhodonite	Rhodonite	...	
	Tetrahedrite	Tetrahedrite	Tetrahedrite	Tetrahedrite	Tetrahedrite.
	...	...	Enargite	...	
	...	...	Bournonite	...	
	...	...	Zinkenite	...	
	...	...	Guitermanite	...	
	...	...	Hübnerite	...	
	(Bismuth compounds).	...	Bismuthinite	...	
4. Contact metamorphic minerals	...	Brown garnet	...	...	Garnet.
	...	Epidote	...	...	Epidote.
	...	Actinolite	...	...	
	...	Tremolite	...	...	
	...	Magnetite	...	...	Magnetite.
	...	...	...	...	Vesuvianite.
	...	...	...	...	Wollastonite.
	...	...	...	...	Specularite.
	...	...	...	...	Chlorite.
Minerals of the deep vein zone	...	...	Specularite	...	
	...	...	...	Zoisite	
	...	...	...	Spinel	
	...	...	...	Picotite	
	...	...	...	Magnetite	
	...	...	...	Biotite	
	...	...	...	Garnet	

TABLE 1.—*Comparative mineralogy of the San Juan region*—Continued.

	Lake City.	Ouray.	Silverton.	Telluride.	Rico.
6. Persistent minerals				Apatite	
	Quartz	Quartz	Quartz	Quartz	Quartz.
	Calcite	Calcite	Calcite	Calcite	Calcite.
		Dolomite	Dolomite	Dolomite	
	Fluorite		Fluorite	Fluorite	Fluorite.
	Chalcopyrite	Chalcopyrite	Chalcopyrite	Chalcopyrite	Chalcopyrite.
	Galena	Galena	Galena	Galena	
	Sphalerite	Sphalerite	Sphalerite	Sphalerite	Sphalerite.
	Stibnite		Stibnite		
			Molybdenite		
	Tellurides	Tellurides	Tellurides		
		Gold	Gold	Gold	
				Arsenopyrite	
	Pyrite	Pyrite	Pyrite	Pyrite	Pyrite.
				Siderite	

In placing the rich silver minerals proustite, pyrargyrite, stephanite, and polybasite in the list of those produced by secondary sulphide enrichment the writers have followed mostly the results of personal observations, but to some extent also the descriptions of Ransome [1] and Purington.[2] Proustite and pyrargyrite are without question of secondary origin in the ore deposits of Lake City and Ouray (pp. 62–63). From Ransome's and Purington's descriptions it seems probable that they are secondary in Rico and in Silverton also. Stephanite and polybasite are described by Purington and Ransome as the last-formed minerals of the veins in which they occur, and in the writers' judgment they should also be placed in the secondary sulphide column for both the Silverton and Telluride districts.

MINERALOGICAL SIMILARITY.

Disregarding for the moment the contact metamorphic deposits, a general view of the table shows that the veins of the San Juan region exhibit a fairly close mineralogical similarity in their most common primary constituents. They are characterized chiefly by pyrite, argentiferous galena, sphalerite, and tetrahedrite, with a gangue composed largely of quartz with subordinate rhodochrosite and other carbonates. Little of the argentiferous galena is rich in silver in any of these districts unless it is accompanied by tetrahedrite or some rich secondary silver mineral. Gold is commonly subordinate in value to silver, notable exceptions being in the Golden Fleece, Camp Bird, and some other mines. Fluorite is rare and almost lacking in the Lake City region. Chalcopyrite is almost universally present in some part of every vein, but generally in less amount than the other minerals. The relative abundance of these primary minerals, of course, varies locally and could serve as a basis

[1] Ransome, F. L., A report on the economic geology of the Silverton quadrangle, Colorado: Bull. U. S. Geol. Survey No. 182, 1901; Ore deposits of the Rico Mountains, Colorado: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, 1901, pp. 229 et. seq.

[2] Purington, C. W., Preliminary report on the mining industries of the Telluride quadrangle, Colorado: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 751 et seq.

for partial subdivision, but the differences are either in the minor constituents which characterize those minerals now known to be secondary (stromeyerite, argentite, etc.), or represent merely local preponderances.

In the Lake City and Ouray regions (columns 1 and 2 of Table 1) all minerals characteristic of the deeper vein zones are completely lacking. In the Rico region, except in certain contact-metamorphic deposits, the veins again show a striking want of any minerals characteristic of deep-vein formation. In the Silverton region specularite is a not uncommon vein mineral, perhaps indicating an approach to a deeper zone of mineralization than is characteristic of the Lake City lodes. In the Telluride region the presence of zoisite, spinel, picotite, magnetite, biotite, and garnet, associated with the minerals which characterize the veins throughout the region, seems to indicate formation at greater depths than in the other districts. This is not absolutely certain, however, as the exact nature of the deposits of these minerals is not stated by Purington.

In both the Rico and Ouray regions contact-metamorphic deposits occur where intrusive monzonite intersects or is in close proximity to limestone. These deposits are characterized by magnetite, pyrite, sphalerite, chalcopyrite, wollastonite, garnet, epidote, specularite, and chlorite. Deposits of this type have with little doubt originated under conditions of high temperature and great pressures, and they are usually regarded as belonging to the deep zone. There seems no good reason to believe that in the Ouray region they represent a period of ore deposition very widely separated from that of the normal lodes and replacements, but they were probably formed long enough before the overlying cover of rock had been sufficiently eroded and the upper part of the monzonite mass become sufficiently cooled to permit the formation of the veins of shallower depth that chiefly characterize these districts and in many places intersect the monzonite itself. The added temperature and pressure which these contact-metamorphic deposits imply would then have been caused by the aggressive entrance of the heated intrusions of monzonite. The first effect would be the formation of contact deposits where this rock had intersected limestones. The subsequent cooling of the more deeply buried mass would have permitted the escape of the vein-forming vapors which produced the normal lodes. For these reasons the contact-metamorphic occurrences cited seem to the writers to have little bearing on the depth of the general ore formation of the region, but to have been rather the result of local conditions.

In general, then, the Lake City lodes may be regarded mineralogically as the outer or northeasterly edge of the heavily mineralized area of the San Juan. The lodes occur at a slightly older geologic horizon than in the other districts and are definitely characterized by formation at moderate depths. The Rico deposits may be considered as on the southern periphery and the Ouray veins as on the northern periphery of the main mineralized region. In these three districts minerals of comparatively shallow formation alone occur. The ores of Silverton and Telluride, on the other hand, may be regarded as having been formed in the heart of the mineralized region where hydrothermal and eruptive activity was most intense, where veins were formed under conditions of high temperature and pressure, and where deposition occurred under heavier cover of overlying volcanics. In these districts a few minerals of the deeper vein zone occur.

ORE DEPOSITS OF LAKE CITY DISTRICT.

THE LODES.

GENERAL CHARACTER.

The lodes of the Lake City area are fissure veins. In the ordinary understanding of the term a fissure vein is a crack or crevice in the rock filled with later-introduced vein material. The Lake City lodes are only in part of this type. They have also been formed largely by replacement and exhibit all stages of the transition from a simple filled fissure, whose walls have been comparatively little affected by vein-forming solutions, to a zone of sheeting and brecciation where most of the mass of vein material has been produced by the alteration of the inclosing rock. Both types of mineralization are common in the same lode, one prevailing in one part, the other in another. In the Golden Wonder lode in Deadman Gulch the fractures are ill defined and the replacement has been extensive and irregular. This is perhaps the one deposit in the Lake City district that may be termed a characteristic replacement as distinguished from a fissure vein.

Ransome[1] has used the term "lode fissure" for those veins whose included mineral has been largely introduced through small, closely spaced fractures, from which solutions have replaced the intervening rock. The Lake City lodes are in the nature of "lode fissures," but, as already stated, so many of them verge toward a simple filled fissure that a clean line of division can not as a rule be made. In some places, as in the Golden Fleece mine, the vein, although it has a very well-defined linear form, consists of a broken zone in which the filling of interstices between rock fragments has been the dominant process, and replacement has been secondary in spite of the extremely broken and shattered character of the zone of mineralization. This vein is discussed more fully on pages 104–111.

Included fragments are present in all of the lodes, and many of the fragments show a very high degree of alteration, but some have

[1] Ransome, F. L., A report on the economic geology of the Silverton quadrangle, Colo.: Bull. U. S. Geol. Survey No. 182, 1901.

been simply surrounded by vein material and have undergone little alteration from the introduction of mineralizing water.

MECHANICAL DISINTEGRATION.

In a region like that at Lake City, where the land surfaces are precipitous, erosion proceeds with great rapidity and the veins have consequently been much dissected. The difference between the lowest and highest topographic points (8,758 and 14,306 above sea level) within the mineralized region is 5,548 feet. The highest point in the outcrop of the several veins examined is 12,800 feet and the deepest point that has been reached in mining on any vein is 7,900 feet. So far as yet determined, therefore, it appears that the veins extend over a vertical range of 5,000 feet. The rarity of mineralized outcrops above an altitude of 11,000 feet renders it probable that their upper limit does not extend much beyond this level. If the length of the Ute-Hidden Treasure vein be regarded as an approximate indication of the depth of the fissure (p. 39), we should have a presumable lower limit of known fissure formation of 7,400 feet.[1] It would therefore appear that the formation of the known Lake City fissures has taken place within a vertical range of 5,400 feet and that almost the entire range of fissure formation is revealed in one place or another by the deep erosion. The mechanical disintegration of the lodes has, moreover, proceeded with great rapidity, for slopes are steep and frost action through a large part of the year relatively intense. Owing to the deep erosion of the country rock in which the veins are contained, great lengths of outcrop have been developed.

As a further consequence of the steep and precipitous nature of the land surface, the veins show fairly well on slopes. Because of the glacial and landslide action, débris has accumulated near the stream levels and has covered the outcrops there, leaving the veins exposed high up on the mountain slopes only. Hence the original discovery shafts on a great many of the properties have been sunk at rather high elevations and carried down to a depth that would ordinarily give the operators an idea of the dip and strike of the lode. The intersection of dipping veins with the steep surface, however, leads to confusion, so that further exploration is generally made by crosscut. Often these crosscuts are unsuccessful, this being due to the fact that after a vein attains any depth in this region it generally undergoes a great change in vein filling and suffers a marked decrease in values. Hence, if cut at all (and often it is not), its appearance is so different that it is seldom recognized as the one that was worked four or five hundred feet above. If the vein were stripped for a vertical distance of several hundred feet down the slope, and drifts run on it, there would be less doubt as to its identity, and as work

[1] Irving, J. D., Ore deposits of the Ouray district, Colo.: B[illegible] No. 260, 1904, p. 59.

progressed the operators might judge whether the work was worth continuing. With everything in sight there would be less dead work and uncertainty, and the cost of stripping the vein would generally be far less than the expense of running a long crosscut.

Where veins have been sufficiently well disclosed to make certain of their continuation in depth their operation by means of crosscuts or drifts has been of distinct advantage, as these have afforded easy drainage and have permitted the development of much stoping ground at moderate cost.

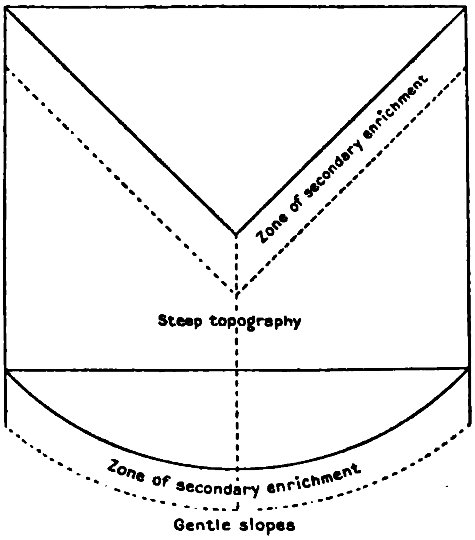

FIGURE 3.—Relation of erosion to superficial alteration.

The steep slopes have not only been of great advantage in exploitation but, in view of the nature of the oxidation and secondary enrichment, have been one of the most valuable assets of the district. If the ores several hundred feet below the surface were as good as those near the upper levels, this would not be so. As conditions are it is most fortunate, for the zone of secondary enrichment is near the surface and nowhere else, and the number of linear feet along the veins is much increased by the steepness of the slopes. Figure 3 shows the relative zones of secondary enrichment for a given horizontal distance in countries with steep and gentle topography. In the latter type there is obviously less enrichment for a given horizontal distance on the vein.

DIMENSIONS.

The following table gives the dimensions of those fissures which have been most satisfactorily explored:

Dimensions of Lake City lodes.

	Length.	Depth.	Width.[a]
	Feet.	*Feet.*	*Feet.*
Lellie	720+	700	0.5–4
Ulay	380+	1,600	5
Ute-Hidden Treasure	2,700+	1,400+	4
Pelican	900+	275+	0.3–4
Missouri Favourite	350+	400+	0.8–2
Nellie M.	700+	500+	2
Monte Queen	950+	600+	3
Black Crook	1,965	1,300	1.5–8
Contention	700+	700	1.5
Golden Fleece	1,300	1,464	0.5–10
Moro-Hendrison	2,000	500	1.2–3

[a] These figures represent rough estimates. They cover vein filling only, not altered or replaced parts of vein walls.

In this region, as in nearly all mining districts, data regarding the dimensions of fissures can be obtained only within the limits of mining operation. Veins are seldom worked to their terminations. The plus sign has been used in the table to indicate that the vein continues beyond the limit of exploration. Where the plus sign has been omitted the work has been continued beyond the point of profitable extraction and has explored the fissure to its apparent termination. The same remarks apply to the depth, although this has been more frequently determined definitely than the extension on the strike.

In length the Lake City veins average between 1,000 and 1,200 feet. Exceptionally strong wide lodes, such as the Ute-Hidden Treasure vein, Black Crook, and Golden Fleece, extend for nearly 3,000 feet. The vertical range of the fissures seems to be about equal to their explored lengths along the strike. The depths in the table given are not the depths of the shafts but the vertical distance between the highest point on the outcrop and the deepest part of the vein below this point. In a great many mines work has ceased before the vein has disappeared, especially where adit tunnels have not been run at lower levels to search for the continuation of the vein. Among the exceptionally long veins is the Moro-Hendrison, which has a length of 2,000 feet, if the correlation of its two parts on either side of the small gulch is correct. It probably represents the root of a fissure, the greater portion of which has been removed by erosion. The Vermont-Ocean Wave-Wave of the Ocean vein is also a vein root. The workings on this vein are now practically inaccessible, so that the writers were unable to determine whether they are all on the same fissure or not, but from the surface outcrops it seems very probable that they are. The vein is fairly straight, for the curves indicated on the map are in large measure due to the effect of topography on the southward dip. If these veins form a single continuous fissure, its total length is over 5,000 feet. The Vermont tunnel, run from the bottom of Henson Creek to tap the vein 1,100 feet below the highest point on the outcrop, has been a failure. Admission to this tunnel could not be secured, but it was reported that the vein was not discovered in the workings, and it is probable that it pinched out above the tunnel level. The Red Rover tunnel, which should have intersected this fissure, disclosed no indication of it. The probability that this vein is a fissure whose upper portions have been completely eroded and whose roots alone remain is strengthened by the extremely rich ores discovered in the upper workings and their very rapid impoverishment with depth. A strong contrast between primary vein filling, such as occurs in the roots of fissures, and secondary enrichment products is, in the writers' opinion, an indisputable proof of the previous existence of a very large vertical range of material from which this rich secondary ore can have been derived and concentrated. In other words, the greater the contrast between the secondary and oxidized ores and the primary ore, the nearer is the approach to the point at which the vein may be expected to disappear completely.

The widths of the veins in the Lake City region vary between a few inches and 20 feet. The average is approximately 18 inches. Many veins were wider in their upper portions and grew gradually narrower with depth. This was the case in the Lellie, Ulay, Black Crook, Golden Fleece, and Vermont. Practically all veins explored by deep workings have pinched out almost entirely. Few widths of 20 feet are found and these extend for short distances only. That in the Hidden Treasure mine was apparently produced by the intersection of a branch vein. Widths of 8 and 10 feet are found in a few places in the Ute and Black Crook veins and according to report in certain portions of the Golden Fleece vein. Pinches and swells in the vein occur both in strike and in depth, and it is, indeed, to these that the division of ore into shoots is chiefly due. Even the Ute vein, which is a singularly uniformly wide fissure throughout its length and probably approaches more nearly to the ideal type of fissure vein than any other in the region, is notably irregular and subject to many pinches and swells in its extension into the Hidden Treasure ground.

TERMINATIONS.

Veins that terminate in depth either narrow into a single small nssure, as in the Lellie, Black Crook, and Golden Fleece, or divide into a number of stringers which finally disappear entirely. Terminations along the strike usually show a division into many branches which finally disappear, as at the southwest extremity of the Ute vein. A sufficient number of examples, however, could not be examined to justify any general rule. As all of the upper terminations of the fissures are now eroded, their extremities in that direction could not be studied.

STRIKE.

Along the strike none of the veins are straight, but twist and turn, generally with sharp angles, somewhat in the manner of a flash of lightning. This is admirably brought out by the plans of the Pelican and other veins. Some of the veins seem to have formed along two intersecting lines of weakness; branch veinlets continue along the old direction, though the main vein assumes a new trend. (See fig. 5.) A marked conformity of jointing and vein direction prevails throughout the district.

Most of the veins in the Lake City area strike in one or the other of two general directions, northeast-southwest and northwest-southeast. The richest lodes trend northeast, but this is probably of little significance so far as the relation of the ore deposits to the geology is concerned. The prominent directions of jointing are approximately the same as those of the fissures. The directions correspond in general to those prevalent in the Silverton quadrangle, although,

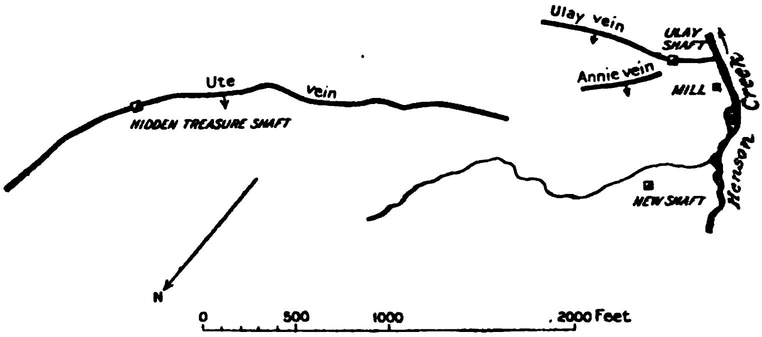

FIGURE 4.—Sketch plan of the Ute-Hidden Treasure group of veins, showing their relations to one another.

contrary to natural supposition, the prominent veins in the southwest portion of the Lake City quadrangle do not have the same prevailing direction as those in the immediately adjoining northeast portion of the Silverton, the predominant veins in the former striking northwest-southeast and, according to Ransome,[1] the predominant veins in the latter striking northeast-southwest.

DIP.

Nearly all the lodes have steep dips, ranging from 45° to 90°. Only one with a dip less than 50° is known, and that one continues for only a short distance. A few veins are practically vertical. The common inclination is between 60° and 70°. In the Capitol City group of veins the dip is uniformly east, but in the other more widely scattered fissures it varies greatly, dipping here on one side and there on the other. In depth the dips are nearly as irregular. Where there has been much movement this feature has also produced differences in width of the veins along the dip similar to those which occur along the strike.

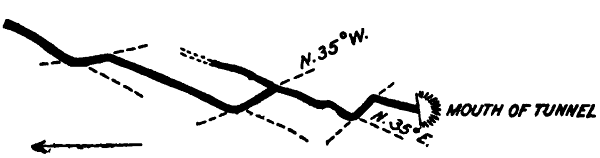

FIGURE 5.—Sketch of typical "forked lightning" fissure vein.

INTERSECTIONS.

Intersections of fissures with different trends undoubtedly take place in many veins, but they can seldom be observed. The Ilma

[1] Ransome, F. L., Economic geology of Silverton quadrangle, Colo.: Bull. U. S. Geol. Survey No. 182, 1901, p. 46.

vein, which runs nearly north and south, intersects the Golden Fleece vein. The actual intersection can not be observed, but it lies on the eastern boundary of the rich ore shoot, which is the most prominent feature of the Golden Fleece vein, and with little question had some effect in producing this ore body.

FAULTS.

Slickensides are common in the Lake City fissures, but they generally indicate movement subsequent to the vein filling. Displacements undoubtedly exist between the two walls of any single fissure, and the large quantities of breccia fragments included in most of the fissures, the prevalence of pinches and swells in the veins, and the selvage clays commonly noted point to some movement between vein walls. The extent of this can not be determined, as there are no recognizable beds in the alternating complex of volcanics to serve as a basis of measurement. It is believed, however, that the faulting along fissures has in general been comparatively slight.

Few of the lodes are disturbed by later movement. A definite fault was observed in the Ilma vein which displaces the vein 35 feet, and post-mineral faulting was observed in the Gallic ore body.

ORIGIN OF THE LODES.

Too few fissures have been explored in the Lake City country to permit any generalization as to their origin. It seems probable that they were produced by the same causes that gave rise to the fissures in Silverton, Ouray, and Telluride. These causes were undoubtedly operative subsequent to the invasion of the volcanic series by the monzonite masses, for some of the fissures cut this rock. It is believed that the fissures were produced by compressive strains due possibly to the gravitative readjustment which accompanied recent movements in the region.

In general, the writers believe that there is no evidence for attributing different ages of formation to the lodes which have different trends. They are believed to have been formed during a single period of fissure formation and to have been mineralized also during a single period.

DISTRIBUTION OF THE LODES.

Most of the veins of the Lake City mining district are located on the slopes of gulches which drain into Henson Creek. A few are on the slope north of the Lake Fork of the Gunnison. Of these two localities the former is a part of the Lake City quadrangle, and the latter is so near it and of such historic interest that it has been thought advisable to incorporate it in the report on this area.

The veins shown on the map (Pl. I) are those that have been worked, and they were in all probability the most easily discoverable in the district. The writers see no geologic reason why the veins should be so segregated as the map indicates, and they are inclined to think that others exist which may prove equally valuable if discovered. In other words, the area is one in which local conditions have not been the cause of the formation of fissures and the subsequent filling with vein material. The conditions were widespread and it is only natural to suppose that the processes which formed one vein have been equally active in other parts of the mining district proper.

FISSURE FILLING AND METASOMATISM.

Mineral solutions which have penetrated the fissures have deposited gangue and ore minerals in them and have altered the adjoining rock. In very few fissures is alteration of the wall rock entirely lacking, and in some of them (pp. 113–114) it has been so extreme that the entire ore mass in the mine is to be attributed to it. In general, however, silicification and sericitization have been the predominant types of alteration. These have resulted in a very fine-grained dense-black jasperoid material which in places extends 4 or 5 feet from the vein filling. Fragments of included rock have been especially subjected to this type of alteration and are usually spoken of in the mines as black quartz. A later alteration of this black material is not uncommon and a light-green margin has been developed extending from a fraction of an inch to 6 inches from the vein filling into the previously altered country rock. Many included fragments have been completely altered to this light-green material, but small cores having the shape of the fragment are not uncommonly left in the center. Microscopic study of the black material shows that it is composed of very finely divided secondary silica and a great abundance of extremely minute particles of sericite. The greenish material is generally marked by the coarser crystallization of the quartz and a relatively smaller quantity of sericite. (The original rock is either an andesite breccia or a solid andesite with glassy or cryptocrystalline groundmass.) Barite, rhodochrosite, sphalerite, galena, and tetrahedrite replacing the wall rock beyond the limits of the open spaces have not been observed by the writers. Their occurrence, however, as distinct crystals in the black silicified fragments shows that they have been deposited either as replacements of an already altered country rock or have replaced these fragments previous to their silicification. Pyrite, on the other hand, commonly extends into the country rock farther than even the silicification and sericitization. It is then well crystallized into minute cubes. Studies of the paragenesis of the ores indicate that the pyrite, silica, and sericite represent the earlier stages of vein formation and are probably the first results of solutions entering the fissures.

BANDING.

Where fissures have been filled with ore minerals or where included plates of country rock have been completely replaced, banded structure is commonly well developed. This is the case in the ore from the Hidden Treasure, also in the ore from the new shaft of the Ulay mine. The ore in the Ute vein is also roughly banded. No specimen observed, however, shows well-developed comb structure throughout the vein. Almost universally one band grades into another, making it in many places impossible to determine the relative ages of formation. It may be said, however, that white crystalline quartz is as a rule the latest mineral deposited. It commonly cements shattered galena and sphalerite or chalcopyrite, rhodochrosite, and tetrahedrite. It also coats crystals of barite which project into cavities. The tetrahedrite in veins belonging to the tetrahedrite-rhodochrosite group (see p. 47), is later in formation than the galena, as it permeates that mineral in many places along cracks and fractures. It is generally closely associated with the rhodochrosite, being commonly scattered through the rhodochrosite mass without any regularity. In general, silicification and sericitization of the country rock was followed by the deposition of vein minerals in the following order: (1) Pyrite in the wall rock and in the fissure; (2) rhodochrosite-galena-sphalerite; (3) tetrahedrite; (4) white crystalline quartz; (5) secondary sulphide-enrichment minerals. In many places, however, the sphalerite, galena, and rhodochrosite show reversals in the order of their formation, and in many it is difficult if not impossible to determine their relative ages with any certainty.

MINERALIZATION.

AGE.

The veins of the Lake City region cut all flow rocks except the Potosi volcanic series and the still later rhyolites and basalts. They cut even the monzonite porphyry intrusions, which are believed to be of late Eocene age. The vulcan vein cut in the Gallic tunnel passes through both monzonite porphyry and andesite, and the Chord Extension vein occupies a fissure entirely in monzonite porphyry, both furnishing conclusive evidence that the fissuring has taken place since the latest injection of magma. Further exploration in the Lake City district may reveal veins cutting the Potosi lavas; in the northern part of the Telluride quadrangle, the veins do cut the Potosi and are mineralized therein, though perhaps not so frequently as in the lower and older rocks; and some of the Silverton lodes cut the Potosi. If the mineralization took place at approximately the same period in these three regions, it is evidently post-Potosi; that is, late Miocene or early Pliocene in age. Ransome believes that the formation of the veins in the Silverton region extended even into the Pliocene. However, there is no way of definitely proving that the veins were formed contemporaneously, and so no fixed age can be given to the period of vein formation and mineralization.

Some connection may exist between the fissuring of the region and the intrusion of the porphyry; for instance, the fissures may have relieved the strains caused by the intrusives. Besides the first great period of fissuring there have been at least two subsequent periods of displacement. In the Gallic mine there is evidence of a primary deposition of ore and gangue minerals, followed by faulting and fissuring, with brecciation of the country rock and vein material, which was later recemented by a second deposition of quartz carrying various ore minerals. A third period of movement is shown by the seams of gouge which are present in different parts of the mine. The Woodstock prospect in Yellowstone Gulch shows evidences of a brecciated vein recemented by a second deposition of quartz. Probably all of the disturbances which have occurred since the original veins were formed have been of a minor character.

EFFECT OF COUNTRY ROCK.

The effect of the country rock upon the vein filling has apparently been of no marked consequence for the minerals in many of the vein vary at places where no change occurs in the wall rock and, on th other hand, veins whose mineralogy is the same throughout occur i all of the rock formations. The Hidden Treasure mine, located i andesite of Picayune volcanic group, has a gangue of rhodochrosit barite, quartz, and fluorite. The Ute, a continuation of the sa vein, has quartz and barite. The prospects in and around Owl Gul which are in the same formation as the Ute and Hidden Treasure, h mainly quartz. Mines in Eureka rhyolite in Yellowstone Gulch h quartz as the predominant vein filling, but the Pelican, in the sa formation east of Sugarloaf Rock, has barite. Barite is also t prevalent gangue mineral in the Missouri Favorite. Evidently t nature of the country rock was not the dominant factor in the depos tion of the vein minerals.

RELATIVE ABUNDANCE OF MINERALS.

MINERAL GROUPS.

A preliminary idea of the mineralogy of the Lake City district h been given in Table 1 (p. 34), which was compiled to show the miner relations among the districts of the San Juan region. More detaile data are given in Table 2 (opposite), in which the relative abundanc of the minerals in the mines is shown by the size and character o the type. The list of minerals has been made as complete as the conditions would permit, but it is probable that it would have shown much greater variety if all parts of the lodes had been accessible. Some errors may also have crept in through inaccurate identification, but in general the list is believed to be fairly accurate.

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	BARITE	
	Barite(?)	
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	BARITE	
No	Barite	RHOD
	Barite	
	Barite	
	Barite	
	BARITE	Rhodo
	Barite	Rhodo
		Rhodoc
So	Barite	

SPHALERITE, (2) Sphaler

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It is impossible to divide the lodes into groups separated by absolutely sharp and characteristic mineralogical differences. They may, however, be divided, according to the relative abundance of their component minerals, into three fairly distinct types, which, designated by their most distinctive minerals, are the tetrahedrite-rhodochrosite group, the quartz-galena-sphalerite group, and the telluride group. These groups, especially the first two, merge into one another at many localities and are without doubt due rather to local variations in the nature of solutions than to separate periods of mineralization.

TETRAHEDRITE-RHODOCHROSITE GROUP.

The tetrahedrite-rhodochrosite group of veins comprises those whose ores consist of dominant galena and argentiferous tetrahedrite with considerable sphalerite and some pyrite in a gangue composed chiefly of quartz, rhodochrosite, and barite. The distinctive or diagnostic minerals in this group of veins are preponderating tetrahedrite, rhodochrosite, and abundant barite. Pyrite is usually subordinate in quantity. Chalcopyrite is also subordinate. Gold values are invariably low and the veins produce chiefly lead and silver. Copper is a by-product. Zinc is not generally present in paying quantities and unless saved in the mill is objectionable. The unenriched primary ore in these veins varies in silver value in accordance with the proportion of silver-bearing tetrahedrite which is present. The gold seems more closely associated with the pyrite than any other mineral. Local increases in chalcopyrite sometimes render the copper values important. The mines whose ores fall into this class are the following:

Hidden Treasure.
Missouri Favorite.
Ute and Ulay.
Pride of America.
Casino.
Lellie.
Vermont.
Ocean Wave.
Wave of the Ocean.
Black Crook.
Belle of the West (?).
Contention.
Silver Chord Extension.

QUARTZ-GALENA-SPHALERITE GROUP.

The veins of the quartz-galena-sphalerite group are characterized by dominant galena and sphalerite with usually subordinate chalcopyrite in a quartz gangue. Barite is either absent entirely or very subordinate in quantity. Tetrahedrite is present in many mines, but is not prominent. It is, however, sufficiently abundant to yield with the argentiferous galena, the rich secondary minerals which have enabled the mines to produce silver as their most important product. Gold values are a little more important than in veins of the tetrahedrite-rhodochrosite type and seem to be associated with the larger quantities of pyrite present in the veins of this group.

Copper and lead are both important products, and in some mines the sphalerite itself is sufficiently abundant to yield profitable returns.

Two or three of the mines of the tetrahedrite-rhodochrosite and quartz-galena-sphalerite groups show transitions one toward another. The Silver Chord Extension mine, though located in the midst of the series of coordinate lodes belonging to the quartz-galena-sphalerite type, shows all of the characteristics of the tetrahedrite series. Again, the Ute vein, the most productive vein in the region, shows affinities toward the quartz-galena-sphalerite type in the Ute ground, but farther north in the Hidden Treasure ground is distinctly a member of the tetrahedrite series. In other mines some shoots show affinities toward one group and other shoots in the same vein show affinities toward the other group. It is obvious that no sharp line of demarcation exists between the two groups, and it is therefore probable that they belong to a single period of mineralization and were contemporaneous in their origin.

TELLURIDE GROUP.

The telluride group consists of veins containing tellurides disseminated through a fine-grained quartz gangue (Golden Fleece), with subordinate galena, sphalerite, pyrite, chalcopyrite, tetrahedrite, hinsdalite and barite. If it were not for the tellurides it would be impossible to distinguish these veins from those of the normal tetrahedrite group; but as the tellurides are entirely absent in the other vein types, they set the former sharply apart. The presence in the Golden Fleece of hinsdalite associated closely with tellurides gives to this vein a somewhat unique character. Neither the telluride nor the hinsdalite are, in the writers' opinion, sufficient to indicate that the Golden Fleece vein has an origin different from the other veins or belongs to a separate period of mineralization. It rather seems to be a variation from the normal type, such as may be frequently encountered in almost any connected area of mineralization. The products of the telluride group are both silver and gold. In the Gallic-Vulcan mine the silver would probably predominate if the mine were of productive size. In the Golden Fleece the proportion by value of gold and silver in the ore was approximately 1:1 (see pp. 110–111), a very much higher proportion of gold than is characteristic of any of the other mines.

SOURCE OF MINERALIZATION.

It is hardly within the province of a brief paper dealing with a small portion of an extensive mineralized region such as the San Juan to enter into an extended discussion of the problems connected with the origin of the ores. Both Ransome [1] and Purington [2] have dis-

[1] Bull. U. S. Geol. Survey No. 182, 1901, pp. 132–141.

[2] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 819–824.

cussed the genesis of the San Juan lodes at considerable length, and inasmuch as the Lake City lodes are probably of the same origin a further discussion may seem redundant. Nevertheless, since later study of genetic problems has led to results applicable to the Lake City and the other related San Juan lodes, some suggestive thoughts seem worthy of presentation in connection with this question.

The explanations offered to account for the filling of mineral veins have of late centered around two opposing hypotheses; the first holds that meteoric waters have dissolved out minute quantities of metallic and nonmetallic elements from the country rocks, have descended into regions of elevated temperature, become heated, and have risen up through fissures and deposited their burden in mineral veins. The second holds that the metals and the accompanying elements and moisture have been component parts of deep-seated eruptive magmas and have, as a final stage of the cooling of the magmas, been released, have found their way upward and have been deposited as ores in mineral veins. A compromise between the two views has often been advocated in the form of a mingling of waters and contained metals derived from both sources.

To the second theory, that of derivation from eruptive rocks, the name "magmatic" origin is now generally applied. The older term "pneumatolytic" was formerly commonly applied to ores supposed to have this derivation, but was used in a much narrower sense, being applied only to deposits like the Cornwall tin veins, where minerals rich in boron, fluorine, and tin were important constituents, and where the veins were distributed in the immediate vicinity of large deep-seated masses of intrusive igneous rocks.

In his discussion of the San Juan lodes Ransome considers both of these possible modes of origin and dismisses the pneumatolytic as improbable. The following paragraph seems to fairly well epitomize his views:

> The Silverton lodes, as a whole, possess neither the distribution nor the mineralogical characters of those deposits to which, in the light of present knowledge, an essentially pneumatolytic origin can be most safely assigned. The known igneous masses had certainly solidified and probably had lost much of their heat before the lode fissures were formed. It is most probable that the transportation and concentration of the Silverton ores was effected chiefly by meteoric waters, which derived their chemical and mechanical energy mainly from the heat connected with volcanism and from pressure, but possibly in some minor part also from gases and vapors given off at high temperatures by solidifying igneous rocks and taken into the deeper meteoric circulation.

There can be no question that the San Juan lodes possess none of the characters of pneumatolytic deposits in the older and narrower sense of the term either in their mineralogy or in their distribution, by which last is probably meant their occurrence as an aureole of metalliferous deposits about a deep-seated igneous mass. As stated above, however, such a character is not an essential feature of the magmatic origin as now understood.

The minerals formed by any given set of vapors, as the writers understand the question, depend on the temperatures and pressures under which deposition has occurred; and such temperatures and pressures, in their turn, are generally a measure of the distances to which the vapors have migrated from the parent magma since their emission. In other words, the absence of minerals characteristic of pneumatolytic deposits from the San Juan lodes does not signify that these lodes were not deposited from magmatic waters, but simply that those waters had migrated to a zone where temperatures and pressures were so low that the so-called pneumatolytic minerals could not form, because they were unstable compounds under those physical conditions.

The comparative mineralogical table (p. 34) shows that in the adjoining Telluride region a number of minerals characteristic of high temperatures and pressures have actually been deposited; hence in that portion of the San Juan region the requisite conditions of temperature and pressure did in some small measure actually obtain. It seems, therefore, that the mineralogy of the lodes offers no obstacle to this explanation of their derivation from magmatic waters.

The absence of any extensive eruptive masses, however, from which magmatic waters may have had their origin does apparently offer a much more serious difficulty.

Ransome's studies in Silverton, like those of the writers in Ouray and Lake City, show conclusively that the veins, and hence also the contained minerals, cut the monzonites and monzonite porphyries, which, aside from the rhyolites and basalts of post-Potosi age (apparently barren of any mineralization), are the latest manifestation of eruptive activity in the region. The veins are therefore regarded by Ransome as later than the monzonite porphyries and consequently as independent of them in their origin. Hence if the minerals are derived from an igneous source, that source must be some deep mass of later age concerning the presence of which there is no geologic proof.

If the monzonite and monzonite porphyry bodies which cut the extrusive volcanics in the Silverton, Ouray, Lake City, and Telluride regions, and which are in fact widely prevalent intrusive rocks throughout the entire San Juan region, did not precede the fissure formation, they could be regarded with confidence as the igneous rock which has had most to do, not only with these ores but with the others which are so prevalent throughout this mineralized area. This is true because they represent the latest intrusives and because they have not escaped to the surface carrying their vapors with them, but have cooled at depths and have yielded mineralizing waters as a final phase of their consolidation.

To the writers the intersection of the upper and first-cooled portions of the monzonite masses by the fissures does not in the least preclude the deeper portions of the monzonite magma from consideration as the most probable source of these ores. Monzonite, quartz monzonite, granite, and quartz diorite have been so often observed by the writers in association with metalliferous ores that their efficiency as a cause seems to them certainly well established. Moreover, as the emission of gases and vapors is the final phase of consolidation, the outer portions must have cooled sufficiently to permit fracture and venation before the lower portions could have yielded their mineralizers. A close analogue can be seen in this very region in the flow breccias, in which fragments of andesite may be seen embedded in andesite. Both fragment and matrix are portions of the same magma; the fragment merely represents the outer portion cooled first and later ruptured by lava movements and then cemented by still molten andesite. In like manner with the veins, except that here, instead of molten rock and small fragments, emitted vapors and widely separated fractures must be considered. Instances of this kind are too frequent to need extended comment. In the Black Hills of South Dakota the refractory siliceous ores are later in age than the phonolite rocks which represent the latest phase of igneous activity, but from this alkali-rich magma these ores are almost certainly derived.

The potency of the monzonite magma to produce mineral deposits is amply attested by the contact deposits that it has produced in the limestone masses in Ouray and, as shown by Ransome's description, in Rico. Unquestionably these contact deposits with their characteristic minerals are derived from emissions from the magmas in situ. The solidification of the main mass of rock and the final emission of vapors which migrated upward into the fissures, some of which had cut their cooler upper portions, seems to the writers to represent by far the most probable sequence of events by which the San Juan lodes have been produced.

MINERALOGY.

The mineral species of the Lake City district are either primary or secondary. The primary minerals are (1) minerals formed at shallow or moderate depths and (2) persistent minerals common to all depths. The secondary minerals are (1) minerals due to oxidation processes and (2) minerals that result from secondary sulphide enrichment. No minerals characteristic of the deeper zones appear in the Lake City lodes, and (p. 36) it is therefore probable that the latter were formed at moderate depths below the surface. In other words, the covering of superincumbent rock has been lighter in this region than in the adjacent Silverton and Telluride districts.

In the following pages the minerals of shallow and moderate depths are first considered; then those which may be called persistent minerals. Minerals of surficial origin, including oxidation products and minerals due to secondary enrichment, are taken up last.

PRIMARY MINERALS.

MINERALS FORMED AT MODERATE AND SHALLOW DEPTHS.

Tetrahedrite.—Tetrahedrite ($Cu_8Sb_2S_7$) is one of the most prevalent and, because of its silver content, one of the most important ore minerals in the Lake City country. In many places it is conspicuous in the ore, but even where it can be detected with less ease it is very important. In greater or less quantity it is present in all mines of the district and, in fact, is reported in some quantity in nearly all mines of the San Juan region.

Ordinary tetrahedrite of the formula given is usually designated "fahlerz" by the Germans, but this type of the mineral does not predominate in this Lake City region. The copper is almost everywhere partly replaced by silver and the antimony to some extent by arsenic. The following analysis from Genth[1] shows the composition of a nonargentiferous tetrahedrite:

Analysis of tetrahedrite.

Sulphur (S)	25.97
Antimony (Sb)	25.51
Arsenic (As)	3.22
Copper (Cu)	37.68
Iron (Fe)	.64
Zinc (Zn)	7.15
Silver (Ag)	.60
Bismuth (Bi)	.37
Manganese (Mn)	.10

Typical freibergite from Freiberg contains more than 30 per cent of silver. The freibergite found in the Lake City quadrangle carries large proportions of silver, much of it running $200 to $300 to the ton, and some that is nearly pure reaching even 2,500 ounces to the ton. The variety that contains much silver has usually a light steel-gray color and is somewhat more greasy in appearance than the nonargentiferous variety; also, the streak which in normal varieties is gray to black is somewhat reddish in the argentiferous types.

The mineral in these lodes is invariably massive, never in crystals, is commonly mingled intimately with galena, and, in general, is highly argentiferous. The correlative mineral tennantite has not been recognized, and the arsenic is probably not commonly great in amount, for almost all the ores yield pyragyrite and not proustite on secondary alteration.

[1] Genth, F. A., Proc. Am. Philos. Soc., vol. 23, 1885, p. 38.

Bismuth compounds.—The complex sulphur compounds of bismuth are reported in considerable quantities in the Monte Queen mine. A complete analysis of this mineral is not available, so that its exact character is not known. According to the operators it contains high percentages of silver, about 20 per cent of bismuth, and considerable zinc. It is gray in color, resembling tetrahedrite, but containing little or no copper. It seems not unlikely that it results from secondary sulphide enrichment, for it lies close to the oxidized zone and is said to carry much higher percentages of silver than most of the other ore in the Monte Queen mine. Further study, however, is necessary to determine its chemical character and origin.

Barite.—Barite ($BaSO_4$) is abundant in the gangue of the galena-sphalerite veins, especially in those of the variety carrying tetrahedrite, which are developed most characteristically along Henson Creek and near Lake San Cristobal, but is less common in those of the Capitol City type, in which quartz predominates. It is present also in much smaller quantity in the telluride veins, where silica seems to be the predominant gangue. The barite as a rule is an interlocking network of thin plates whose interstices are filled by fine-grained silica or metallic minerals. This structure discloses but little banding and gives a massive appearance to the ore. In many vugs it is developed in very beautiful crystals of considerable size and generally perfect transparency. In a few veins it exceeds all other minerals in quantity, and when this is the case the ore is of little value. The barite is clearly of earlier deposition than the quartz, as the latter frequently incrusts crystals that project into central cavities. Barite is very abundant in the Hidden Treasure portion of the Ute-Hidden Treasure vein. It offers a strong contrast to the quartz in most of the lodes where it is present. Perhaps its commonest association is with the jasperoid or fine-grained quartz described on pages 44 and 60.

Rhodochrosite.—Rhodochrosite ($MnCO_3$) occurs in many of the veins in the Lake City region and in some lodes is absent in one portion and present in great quantity in another. Thus in the Hidden Treasure mine it makes up the bulk of the vein filling in the northern end of the Hidden Treasure ground and is practically absent in the Ute end of the same vein. Again, in the Monte Queen mine it is inconspicuous in most of the stopes but forms a full 5-foot face of solid mineral in the extreme western face of the tunnel. Many of the stopes in the Ilma vein likewise show no evidence of rhodochrosite, though in others it is present in large quantities and is notable for its coarsely crystalline structure and deep red color.

The majority of the rhodochrosite in all of these veins is contained in a very fine-grained aggregate whose individual cleavage faces measure not over 1.5 millimeters. When first mined it is generally deep pink in color but rapidly bleaches on exposure until it has only a slight pinkish tinge which distinguishes it from dolomite. If the exposure be long continued it develops a brownish coating, which makes it resemble siderite unless examined on fresh fracture. Rhombohedral crystals of rhodochrosite are common in cavities, in some of which they are intergrown with quartz. It is probably one of the later minerals deposited. Tetrahedrite is more generally associated with rhodochrosite than with any of the other minerals; so much so that in milling the crushed ore on the Wilfley tables in the Hidden Treasure mill about an inch of rhodochrosite above the line of concentrates and gangue is saved from the tables. This is done because the rhodochrosite contains considerable quantities of silver even if the included particles of tetrahedrite are too fine for observation.

Hinsdalite.—Hinsdalite ($2(PbSr)O.3Al_2O_3.P_2O_5.2SO_3.6H_2O$) was first collected by E. S. Larsen, to whom belongs the credit of its discovery and investigation. Mr. Larsen will soon publish a longer description of it elsewhere. It was first found on the dump at the mouth of one of the tunnels of the Golden Fleece mine, at an elevation of about 9,950 feet, where it is present in considerable amount. It is an

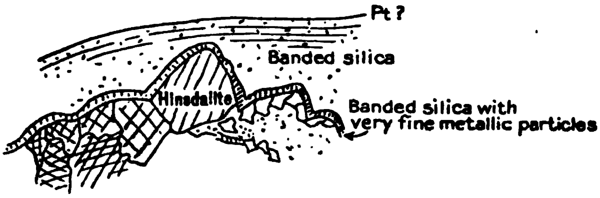

FIGURE 6.—Hinsdalite from the Golden Fleece mine.

original vein mineral associated with quartz and a little pyrite, galenite, tetrahedrite, and barite. It occurs in bands about an inch wide or as crystals imbedded in the grayish chalcedonic quartz which forms the matrix of the petzite in the richest ore. Its crystals are not uniformly well defined as to boundaries, but generally form irregular bodies ranging from minute particles to masses three-fourths of an inch in greatest diameter. The crystals are marked by a very distinct and brilliant cleavage. (See fig. 6.) They are either rhombohedrons, resembling cubes, or pseudohexagonal tablets. If the apparent hexagonal base be taken as the true base, there is a perfect basal cleavage, but the cleavage faces are as a rule wavy and striated. The optical data indicate that the mineral is only pseudohexagonal. Its hardness is about 5; its luster is vitreous to greasy. The fresh mineral is pale greenish, but much of the material is dark gray from inclusions. The streak is colorless.

The indices of refraction are somewhat variable, but the values for the principal zones are about $\alpha=1.670$, $\beta=1.671$, $\gamma=1.688$. Sections normal to the cleavage show parallel extinction, those parallel to the cleavage are generally hexagonal in outline and show the emergence of the positive acute bisectrix. They may easily be taken for uniaxial crystals, as the axial angle is small but variable; 2 E is usually about 32°. Basal sections are generally divided into six radial segments, and the plane of the optic axis in each segment is normal to the pseudohexagonal prism edge.

W. T. Schaller furnished the following analysis, which was made on fresh light-gray crystals of hinsdalite. They were examined microscopically and found to be very pure, but showed a slight zonal growth.

PbO	31.75
SrO	3.11
Al_2O_3	26.47
SO_3	14.13
P_2O_5	14.50
H_2O	10.25
	100.21

CaO, MgO, Na_2O, K_2O, trace.
D=3.64.
Formula $2(Pb\ Sr)O.3Al_2O_3.P_2O_5.2SO_3.6H_2O$.

Hinsdalite is infusible but whitens on heating. It reacts for aluminum when heated with cobalt nitrate and readily yields a button of metallic lead. It is insoluble in acids. The water is driven off only at a temperature of from about 400° to 600° C.

MINERALS FORMED AT ALL DEPTHS.

Pyrite.—Pyrite (FeS_2) is present in all lodes of the region and is by far the most widely distributed of the metal-bearing minerals. It differs in abundance in the different lodes and is generally found in greatest amount in the lower and less valuable portions of the mines. When associated with galena it is more commonly fine grained and shows few crystal faces. It is subordinate in most of the ore in many lodes, especially in those which consist chiefly of galena and tetrahedrite and those which carry tellurides. When galena is in large amount and quartz is the gangue, pyrite is generally insignificant, as in that portion of the Ute vein which contains chiefly argentiferous galena and sphalerite. In the Capitol City series of galena-sphalerite-chalcopyrite ores it is, however, relatively abundant and in some ores is very conspicuous.

Where not contained in tellurides, gold is apparently more generally contained in and associated with pyrite than with any of the other minerals. In this respect the Lake City pyrite closely resembles that described by Purington from Telluride. In the Contention mine the rich silver values contained in the gray copper and its oxidation products contained but little gold, but in the lower levels the vein carried chiefly quartz and pyrite, and in this mixture the gold was commonly notable, yielding a much better average than in the more profitable silver ores above. Similar conditions were found in the Moro mine.

Pyrite is possibly an exception to the general rule (p. 44) that the metallic minerals are not generally present in the country rock, despite the fact that silica in many places penetrates to great distances and transforms the rock into jasperoid, in which phenocrysts and structures of the original are preserved. In places, as in the lower levels of the Contention mine, pyrite replaces the porphyry and occurs as disseminated crystals, few of which measure more than one-fourth inch and nearly all of which are rather perfect cubes, though generally containing pyritohedral striations. Silica and pyrite, singly or together, seem to have had a permeating power strikingly lacking in the other ingredients of the ore.

Coarsely crystalline pyrite is not common in the Lake City veins, nor are large, massive bodies of it seen in any of the veins.

Galena.—Galena (PbS) is absent in few Lake City veins, but its amount varies greatly in the different lodes and in the different portions of any single lode. In some mines, as the Ute-Hidden Treasure, it forms an extremely abundant and very profitable mineral at one end of the lode, and at the other it sinks greatly in amount and is less abundant than tetrahedrite. In the lead-zinc-copper group of Capitol City it shows the most common association with sphalerite, but in the other mines this association is either lacking or is very much less marked. When not associated with sphalerite, it is commonly intimately mixed with tetrahedrite. The mixture can be detected with the naked eye in many specimens, in which the tetrahedrite seems to fill the interstices between shattered fragments of galena (Pride of America, Missouri Favorite, Pelican, and many others). When not apparent to the eye, its presence may be detected by polishing the surface of a mass of rich silver-bearing galena. Indeed, in the writers' opinion, all the high-grade unenriched galena owes its high silver content to tetrahedrite. Little pure galena in the Lake City lodes carries more than 22 ounces in silver to the ton and much of it carries a good deal less. Similar conditions in the Silverton district are recognized by Ransome, who states [1] that the galena there, when free from the richer silver minerals, does not contain very much silver.

The authors polished carefully some faces of normal Lake City galena carrying about 10 to 15 ounces of silver, but were unable to detect any mechanically mixed mineral in it. In this respect the Lake City mineral offers a parallel to some described from England by Finlayson,[2] who found native silver mechanically mixed with much

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[1] Ransome, F. L., A report on the economic geology of the Silverton quadrangle, Colo.: Bull. U. S. Geol. Survey No. 182, 1901, p. 80.

[2] Finlayson, A. M., Ore deposition in lead and zinc veins of Great Britain: Quart. Jour. Geol. Soc. London, vol. 66, 1910, p. 319.

of the silver-bearing galena carrying high values, but could find no trace even under higher powers of mechanically mixed minerals in galena carrying lower values. His inference seems justified that the silver to a certain amount is chemically combined in some manner with lead and sulphur, but that when present in very large amount it exists as intermingled free silver. The difference in the two cases is simply that in the one instance it is native silver and in the other argentiferous tetrahedrite. Much of the galena shows complex twinning, due to crushing stress, and this shows admirably in many polished sections. In most of the lodes the galena is rather coarse, but much of the finer variety, even down to "steel galena," is also found. When associated with sphalerite both are either coarsely crystalline, as in the Ute vein, or are extremely fine-grained, as in the Monte Queen.

Some interesting practical results follow from the study of the high-grade silver-bearing galena. The Lake City ores offer considerable difficulty in milling operations (p. 72), and in the Ute mine especially the greatest difficulty was experienced in recovering a reasonably high proportion of silver. The difficulty in saving the silver in the argentiferous galena is without doubt due to the intermixed tetrahedrite, for this mineral is so easily slimed that it floats away on top of the water, and only canvas tables, of which the writers have seen none in the Lake City region, will save any considerable portion of it. With it goes much of the silver, leaving only the chemically combined silver in the galena.

Fully faceted crystals of galena are commonly seen in vugs in the Capitol City and other ores, but few of them attain notable size.

Sphalerite (zinc blende).—Next to pyrite, zinc blende (ZnS) is the most abundant and most universally distributed mineral in the lodes of the Lake City region. In practically no mines is it entirely lacking, although it is much more abundant in some than in others. Thus in the highly zinciferous lodes of the Capitol City region it is generally present in such large quantities that the endeavor is now being made to produce a concentrate which will run 29 per cent or more in zinc, and thus enable the companies to secure payment for this metal and avoid the high penalties charged by the smelters for ores which run between 10 and 29 per cent in zinc. In much of the gold-bearing telluride ore of the Golden Fleece sphalerite is absent and where present is extremely subordinate in quantity. The telluride ores in the Gallic-Vulcan mine carry notable amounts of extremely dark-colored ferruginous sphalerite. The mineral in this particular mine, as will be later explained, has exercised considerable effect on the secondary precipitation of gold. In the Capitol City lodes, where sphalerite is present in greatest abundance, it is coarsely crystalline and is usually light brown to light green and even pure yellow. Less commonly it has the dark ferruginous character of the iron-bearing types known as "Black Jack." All varieties, however, are present to some extent in most of the mines of the region. The very fine grained, almost massive type is uncommon in the Lake City ores; it does occur, however, notably in the Monte Queen mine, in which the sphalerite is of unusual interest. It is extremely fine grained, approaching the types known from the Friedensville mines in Pennsylvania, is very dark in color, and carries high values of silver and generally notable percentages of bismuth. It has not been possible to determine from the specimens whether the bismuth is present as an individual mineral species or is in some manner combined with the zinc. Certain analyses of much of this ore are reported to show 20 per cent bismuth. High proportions of bismuth are invariably accompanied by increased proportions of silver, and it seems probable that the ore includes a mineral (perhaps a variety of sphalerite) containing both bismuth and silver in chemical combination. In the Ute vein and the other veins of the district the sphalerite is most commonly associated with galena.

In general the sphalerite belongs to one of the earlier periods of mineral deposition. This is noticeable in the Ute vein and the Moro vein, in both of which the sphalerite is much shattered and penetrated by the white quartz which forms a larger portion of the gangue material. Where zinc is prominent and yet is not sufficiently abundant to be saved it becomes very objectionable and in not a few instances has led to the abandonment of workings.

The vertical range of sphalerite seems to be from the lowest workings in decreasing quantities toward the surface. In the Ute mine all the veins carry a very large increase in this mineral with depth. The Ulay vein, the Ute vein, and the new vein recently opened in the west shaft contain large quantities of zinc and show a decrease in silver content so great that the ore can not be handled profitably. The same is true of some of the Capitol City mines.

Chalcopyrite.—Chalcopyrite ($CuFeS_2$) is especially abundant in veins that carry neither the tellurides nor notable quantities of tetrahedrite. In subordinate amounts it is present in all the mines. It is always massive, never crystalline, and does not generally carry appreciable quantities of either gold or silver. In the Moro mine and the related veins near Capitol City it is especially abundant. In the Henson Creek mines and those in the vicinity of Lake Fork it is subordinate. Where present in large quantities and intimately mingled with sphalerite the separation of the two minerals in milling operations has been attended with serious difficulty, the specific gravities of the two minerals (sphalerite 3.9–4.2, chalcopyrite 4.1–4.3) being so nearly the same that it is extremely difficult to secure a clean concentrate. For this reason the Moro mine has installed a

Blake-Morscher static electric separator. It is not known whether this has proved successful or not.

Chalcopyrite shares with tetrahedrite the copper production of the district, but copper is in all of the lodes essentially a by-product. Tetrahedrite (gray copper ore), where unaccompanied by silver values, is not an important ore in this district, and it is highly improbable that these veins could have been worked for their copper content alone.

Tellurides.—Tellurides are absent in all except two of the Lake City lodes, the Gallic-Vulcan mine and the Golden Fleece mine. The Gallic-Vulcan has never been productive and interest in it is purely scientific, but the very large proportion of tellurides in the Golden Fleece mine gives to the mineral a high relative importance. It is noteworthy that in Rico, Telluride, and Ouray tellurium compounds are entirely absent and in Silverton they are present only as scientific rarities. Their appearance, therefore, in one or two veins in such large quantities and in the midst of other types of minerals gives to Lake City a feature which serves to distinguish it from the other districts of the San Juan region. Tellurides are also reported to occur in the Isolde mine in the Burrows Park region, but these statements have not been verified, as that mine is outside of the area covered by the present examination.

In the Gallic-Vulcan mines the tellurides occur in small quantities distributed through the vugs in the white quartz which constitutes the larger portion of the vein material. They range in color all the way from lemon yellow through greenish yellow to silver white and steel gray. An insufficient amount of pure material was available for analyses, so that the individual species can not be definitely stated, but from their color and general appearance it is probable that all of the varieties calaverite, sylvanite, krennerite, petzite, and hessite are present.

In the Golden Fleece mine the prevailing telluride is petzite, an iron-gray mineral with a black streak verging toward silver gray. In some places it is distributed in irregular bunches, often of considerable size, through a white, dense, granular quartz; it does not form regular crystals. Elsewhere it is disseminated in extremely fine particles through the chalcedonic quartz, to which it gives a dark-gray color. A great deal of gray copper (tetrahedrite) also occurs in the Golden Fleece mine, and when this mineral is in finely divided particles in the ore a distinction between it and the telluride is difficult. It is significant that the tellurides both in the Golden Fleece and in the Gallic-Vulcan mines occur with tetrahedrite and other minerals, such as characterize the prevailing lodes in the region. These lodes are, therefore, in the writers' opinion, to regarded as local variants of the normal antimonial lead, sil copper, zinc veins characteristic of this region rather than a separate group of telluride lodes of different age and independent origin.

Quartz.—Quartz (SiO_2) is present in the gangue in all the mines of the Lake City region and is probably also the most abundant vein mineral in the district. It occurs in two sharply contrasted varieties, both of which are present in greater or lesser amount in all of the veins. The first of these is a fine-grained aphanitic variety frequently called jasperoid, which ranges in color from almost black, through all shades of gray, to a dense material having the appearance of porcelain. A good deal of this jasperoid is banded and has apparently resulted from deposition in an open space rather than from replacement. Some of it, however, is characterized by small irregular cavities lined with minute quartz crystals (druses); this form has almost universally resulted from the silicification of the country rock and is a product of replacement rather than of deposition in an open cavity. All of these varieties of jasperoid are extremely tough and dense and their true character can not be determined without the microscope. Finely divided metallic minerals, such as tellurides and tetrahedrite, frequently give a darker color to the fine-grained jasperoid.

The second type of quartz is the ordinary white crystalline variety. This is probably the most common type in most of the veins, in the majority of which it exhibits well-developed comb structure and is the commonest lining of vugs. The white quartz occurs without question in more than one generation, but the bulk of it is younger than any of the metallic minerals, for it cuts through sphalerite, galena, tetrahedrite, pyrite, and even rhodochrosite in places. Veinlets of this white quartz also frequently cement shattered masses of the metallic minerals.

Dolomite and calcite.—Dolomite ($[Ca, Mg]CO_3$) and calcite ($CaCO_3$) occur very rarely as individual species in the Lake City veins. Calcite has been identified by the writers with certainty in only a few places; and both these minerals are of such slight importance in the district as to be negligible. In this respect the Lake City veins differ from those in the Telluride and Silverton districts. It is probable, however, that both calcium and magnesium occur, replacing a portion of the manganese in the rhodocrosite, a mineral which is very common in these veins, and giving it a light pink color. Both calcium and magnesium are present in much of the mixed carbonates of the Ouray district, and it is likely that they occur at Lake City also.

SECONDARY MINERALS.

Atmospheric agencies have acted on the minerals of the Lake City lodes to form oxidation products and secondary sulphide enrichment minerals.

OXIDATION PRODUCTS.

An extensive discussion as to the character of oxidized products formed in the outcropping portions of the Lake City lodes is difficult, if not impossible. Few of the outcrops are prominent, many of them being covered with landslide material and with different forms of rock débris, and such workings as have been driven on them are now generally abandoned and inaccessible. For this reason the list of minerals (p. 34) produced during the processes of oxidation would probably be much increased if a more general examination had been possible.

In general the oxidized zones of the Lake City ore deposits are not deep. Thus in the Moro mine oxidation has penetrated to a depth of approximately 100 feet, and on the Ilma vein, near Lake San Cristobal, to about 200 feet. This lack of depth is due in part to the length of the winter season, which, during a large part of the year, undoubtedly prevents access of water to the veins. However, in spite of the large preponderance of run-off over infiltration, a great deal of water has found its way into the lodes, as is evidenced by the extremely rich character of the oxidized ores and the ores produced by secondary sulphide enrichment. Probably a very considerable part of the eroded portions of the lodes has been carried down in solution into the now existing remnants and has enriched them enough to make profitable mining possible. With less rapid erosion, however, the veins would have been very much richer in their upper portions than is actually the case.

The minerals produced by oxidation are:

1. Minerals such as the soluble sulphates, chalcanthite, and melanterite, which have been taken into solution and afterwards partly crystallized out. These soluble sulphates are rare in the Lake City veins, this probably being due to the continued presence of water in the veins, which has kept the minerals in solution and prevented their crystallization.

2. Minerals formed by the reprecipitation of the dissolved constituents. These are limonite, hematite, basic ferric sulphate, pyrolusite, malachite and azurite in small quantities, anglesite, and cerusite. Cerusite is comparatively uncommon in the Lake City lodes, probably on account of the absence of wall rocks containing carbonate of lime. It is, however, present in some quantity in most of the lodes. Anglesite, especially in its fine-grained form, is a very common oxidation product of the lead veins. It occurs almost exclusively in the upper 100 feet of the Moro vein. Limonite is by far the most abundant of all the minerals produced in this way.

3. Minerals which have been precipitated by the reaction of various sulphates on one another. These are native copper and native silver.

In the Excelsior mine a mass of native copper weighing 150 pounds was found in the oxidized zone, and smaller masses have been found elsewhere, though nowhere in sufficient abundance to be a commercial asset. The copper has probably been produced according to the following equation:

$$CuSO_4 + 2FeSO_4 = Cu + Fe_2(SO_4)_3.$$

Native silver is also a frequent by-product of oxidation processes, having probably been formed in the following manner:

$$Ag_2SO_4 + 2FeSO_4 = 2Ag + Fe_2(SO_4)_3.$$

It has not been found, so far as the writers have been able to determine, below the base of the oxidized ore, but it is distributed in considerable quantity among the oxidized minerals. It occurred in the Gallic-Vulcan, Excelsior, Woodstock, Ute, Hidden Treasure, Ilma, Contention, and Golden Fleece mines, and probably also in many other mines concerning whose oxidized ore no data could be secured. It is usually in the form of wire silver and has probably had considerable importance in rendering profitable the oxidized ores.

Native gold is not common in the oxidized ores of any except the telluride veins, and there only to a minor degree. It is present, however, as will be explained later, in the upper part of the zone of secondary sulphide enrichment.

SECONDARY SULPHIDE ENRICHMENT MINERALS.

Secondary sulphide enrichment has been the most important of all the features that have rendered the Lake City lodes commercially profitable. The comparatively low-grade ores which are found on the levels at depths below the reach of all secondary action and the sharply contrasted and very rich masses of bonanza material in the upper levels are the most striking feature of all of the Lake City lodes. To the failure to recognize this distinction is in large part due the disappointing results of so much of the expensive development in the district. The Vermont tunnel, Red Rover tunnel, and Ilma tunnel (Golden Fleece mine) cost large sums of money and have been extremely disappointing.

The minerals produced by secondary alteration are pyrargyrite and proustite, chalcocite, covellite, galena, bornite, native gold, and probably some argentite.

Pyrargyrite and proustite.—The so-called ruby silver ores occurred in large quantity in all of the producing mines, and to their presence the major part of the silver production of the region is to be attributed. The two ruby silver minerals are the antimonial sulphide, pyrargyrite, Ag_3SbS_3 (59.8 per cent Ag), and proustite, Ag_3AsS_3 (65.5 per cent Ag), the one known as dark ruby silver and the other as light ruby silver. The antimonial variety seems to have been by far the most common in the ores mined, but the arsenical variety undoubtedly occurred, and it is likely that indefinite amounts of arsenic replaced the antimony in much of the ore.

Pyrargyrite and proustite are not at present mined to any extent, as they have long since been exhausted, leaving only the tetrahedrite ores from which they were derived. They occurred either disseminated in crevices and cracks in the sulphide ore, as beautiful crystals in vugs, or as irregular bonanza-like masses segregated along cracks and fissures through which descending solutions penetrated into the unaltered sulphides below. A mass weighing several hundred pounds, taken from the Hidden Treasure mine, was exhibited by Dr. Hoffman in Lake City. This ore was very abundant, intermingled with the telluride ore above the third level in the Golden Fleece and in the adjacent Ilma mine. It occurred, so far as could be learned, in all of the mines at the plane of demarcation between sulphides and oxides and, in generally decreasing quantity, to several hundred feet below this level. Along cracks and fissures it occurred in isolated masses to great depths; for instance, at 1,200 feet in the Golden Fleece and at 1,300 feet in the Ilma. These deep occurrences are, however, uncommon and merely indicate the presence of some easy line of access for downward-moving solutions.

Ruby silver has probably resulted from the solutions of silver and antimony obtained by the decomposition of the tetrahedrite and possibly to some extent also from the argentiferous galena. The chemistry of both the solution and reprecipitation of the antimonial and arsenical sulphur compounds has not yet been worked out in sufficient detail to permit a statement of the probable steps of the process, but the geological facts show that it has occurred. The proofs of the secondary character of the ruby silver are:

1. Its restriction in quantity to the upper levels of the mines.
2. Its invariable occurrence as the latest deposited mineral in the veins, either in cracks or crevices in shattered primary ore or as crystals in cavities.
3. Its occurrence only in isolated bunches in deeper workings, where its origin is probably due to the presence of water channels that permit the downward percolation of water from above.
4. Its complete absence from the great mass of deep-seated ore.

It is clearly secondary in all of a large number of specimens of silver ores from the Southwest.

Secondary chalcocite.—Chalcocite (Cu_2S) in the finely divided sooty form is a common constituent of ores high in chalcopyrite and pyrite; in some mines, the Moro, for instance, it extends as deep as 500 feet. As copper is only a minor ingredient in point of value, this mineral is of more scientific than commercial importance.

Covellite.—The indigo-blue sulphide of copper, covellite ($Cu S$), does not occur in quantity, but is found in a number of mines as a product of secondary sulphide enrichment coating the surfaces of sphalerite. The sphalerite at first glance appears to be covellite, as it has the luster, color, and general appearance of that mineral. When lightly tapped it falls to pieces, but shows no change in its color or luster, and only when it is broken up quite small does it exhibit the characteristic cleavage and color of sphalerite. It may then be noticed that the films of covellite are not more than one thirty-second to one sixty-fourth of an inch thick and have been deposited all through the sphalerite. As the covellite is less soluble than sphalerite it is clear why the sphalerite has caused the enrichment.

Bornite.—Bornite (Cu_5FeS_4) is rarely seen and then only as thin films on the surface of chalcopyrite which has been exposed to alteration. In massive form it is absent in these mines.

Secondary galena.—Galena (PbS), as a product of secondary enrichment, is uncommon, this being probably due to the fact that oxy-salts of lead are so much more insoluble than the corresponding salts of other metals that their transportation from place to place goes on in only a minor degree. In many mines which have a large content of coarse-grained sphalerite, however, a thin gray film of metallic character has been deposited in the cracks of shattered sphalerite. This material occurred especially in the Pelican mine. The crystalline form of galena could not be detected under the microscope, but from the analogy of this material with some from other localities where the cubes were of sufficient size to recognize, it is probable that the mineral is galena. The sphalerite, which has been thus enriched, may be broken by the hammer without revealing its true character, as it is so penetrated by lead-lined fractures that especial care has to be taken to break a portion of the mass that has not previously been shattered. When this is done the characteristic cleavage and color of sphalerite at once appear.

Gold.—In the Gallic-Vulcan mine crystals of sphalerite were observed coated with leaves of native gold, the latter mineral having apparently been reduced from solution by the zinc sulphide. This occurrence, though of no commercial importance, is worthy of special note as it has been observed by one of the writers in a number of places, notably in the Ibex mine in Leadville, Colo., where metallic gold coating crystals of sphalerite was discovered in large quantity at about the central part of the sulphide-enrichment zone.

PRECIPITATION DUE TO SPHALERITE.

It is interesting to note that zinc blende in the Lake City veins has frequently exerted an extensive effect in re-precipitating downward-moving sulphates in the form of secondary sulphides. It is not believed that the effect produced by this mineral has been sufficiently considered in most papers on secondary enrichment. Its position in the scale of solubilities of the sulphides is of considerable interest in this connection. It was until recently believed that the series representing the order in which the sulphides of one metal would precipitate the sulphides of the other metals was dependent on the relative affinities of the several metals for oxygen and sulphur. It has been recently shown, however, by Wells,[1] and has appeared also in studies by one of the writers that the relative solubilities of the different sulphides was the determining factor in the precipitation of the secondary sulphides. This series of solubilities arranged in decreasing order is as follows: Mercury, silver, copper, antimony, tin, lead, zinc, nickel, cobalt, iron, arsenic, and manganese. From this it appears that, with the exception of pyrite, sphalerite exercises the greatest effect in the production of secondary minerals in the Lake City veins, as nickel, cobalt, and arsenic are there absent. Chalcocite is probably the only secondary mineral that has not been definitely identified in intimate association with zinc blende. The ability of sphalerite to precipitate native gold presumably from a solution of ferric sulphate and chlorine is also interesting. The high silver content of some of the zinc blende encountered in the Monte Queen mine and in some other mines may perhaps also be explained by the presence of native silver precipitated in like manner.

PAY SHOOTS.

All of the Lake City lodes are characterized by the lateral segregation of workable ores within certain more or less restricted portions of the vein. These restricted portions are usually termed pay shoots, as they may be profitably worked, even though the intervening portions are unprofitable. Such localizations of metalliferous minerals may be due (1) to the widening of the fissure between two constricted portions in which neither ore nor gangue minerals have been deposited in any quantity; and (2) to the segregation of metalliferous minerals within the vein.

The first type of shoots is the most common appearing in the Monte Queen, to some extent in the Hidden Treasure, and in many other mines. An interesting feature of the Monte Queen ore body was the different material in the three known shoots. These are vertical and are formed by the swelling of the vein between pinches that leave only a few sheeting planes with some stringers of quartz, etc., by which the vein may be followed from one shoo t to the next. In the Monte Queen there are three of these shoots (figs. 17 and 18, pp. 100 and 101), with stope lengths measured along the strike of the vein of 50, 75, and 200 feet. Nos. 1 and 3 contain chiefly pyrite

[1] Wells, R. C., The fractional precipitation of sulphides: Econ. Geology, vol. 5, No. 1, 1910, pp. 1-14.

and some gray copper ore but do not carry profitable values in silver. No. 2 consists chiefly of a peculiar rosin-like dark-brown sphalerite, mixed with fine steel galena; it averages about 75 ounces of silver to the ton and from 1 to 20 per cent bismuth. A fourth shoot, 950 feet from the mouth of the tunnel, carries a massive, fine-grained aggregate of rhodochrosite.

Within the limits of the No. 2 shoot additional cross shoots occur (fig. 18) which pitch about 15° from the horizontal within the vertical shoot along the course of the vein to the southeast. These interior shoots are lenticular in cross section and have a vertical range of from 3 to 20 feet, with an intervening barren quartz filling of from 3 to 12 feet. (See figs. 17 and 18.)

Some of the shoots have great length, as for instance in the Ute vein. Here the vein from its southwest end nearly to the Hidden Treasure line, a distance of 3,000 feet, was of workable width and the metallic minerals were distributed with remarkable uniformity throughout its whole length, so that nearly this entire distance constituted a shoot. Shoots are reported to have occurred in the Ulay vein, but the workings are now inaccessible.

The second type of pay shoot is that in which a segregation of valuable minerals within a barren gangue occurs. One in the Golden Fleece mine (see fig. 22, p. 107) pitches to the west about 27° and has a length along the vein of about 300 feet at the surface but pinches down to a point below the third tunnel level. Its pitch is about parallel to the trace of the intersection of the Ilma vein, which has a nearly north and south trend and lies mostly just west of the intersection. It is very probable that this intersection has been the determining factor in the origin of the shoot.

In addition to the segregation of the commercially profitable minerals the gangue minerals also show a localized distribution. Thus, in the Monte Queen mine above mentioned, rhodochrosite is rare in the first three shoots but is almost the only mineral present in the fourth shoot, which shows a total width of 5 feet from wall to wall. In the Hidden Treasure, at the northeast end, rhodochrosite and barite greatly preponderate, but the former is almost wholly absent from the Ute portion of the vein and the latter is present in very much smaller amount.

Other details of shoots can not be given, as too few of the mine workings are now accessible for their accurate study.

VALUE OF THE ORES.

The principal product of the Lake City region has been silver, but lead, gold, and copper have to some extent contributed to the value of the ores. Zinc has had practically no part in the production and has been one of the most objectionable components.

If divided according to gold and silver content, the veins of the region might be classed as silver-bearing veins and gold-bearing veins. The tetrahedrite-rhodochrosite group and the quartz-sphalerite-galena group would fall together in the silver-bearing class and the telluride group in the gold-bearing class. The details of ore values can be ascertained only from oral report for many of the mines, because many workings have been abandoned and records could not be secured. Other workings now ship low-grade ores, whereas those mined in early days were of very much higher grade.

In the silver-bearing group the present ores do not average much over $6 to $10 a ton and yield a concentrate worth about $40 a ton. This includes both the high-grade masses of tetrahedrite scattered through the ore and the lower-grade ores that are also a notable feature. In the upper levels of many mines the ore has ranged from $10 a ton up to $3,000 a ton and even more. Eighty-five shipments of ore of about 25 tons each from the upper levels of the Vermont mine averaged 84.53 ounces silver and 27.96 per cent lead, or approximately $44.80 silver and $12.06 lead, a total gross value of $52.86 per ton; 63 tons mined in 1894 yielded $79 per ton; and two shipments in 1895 and 1896 yielded $22.78 and $22.67 a ton, respectively.

The average of the ore mined in the Hidden Treasure mine in 1898–9 was from $7 to $9 per ton, yielding $41.67 per ton of concentrates. The Black Crook in 1884 produced 1,227 tons of ore valued at $124,447, or about $101.39 per ton. All of these rich ores have now been exhausted and the ore must be milled. Probably very little of the ore runs over $5 to $6 per ton.

Of the telluride or gold-bearing veins the Golden Fleece alone has thus far been a producer. Much of the ore it yielded during its early exploitation was of unusually high grade. The following figures, kindly furnished by Mr. George W. Pierce, show the grades of ore mined and milled:

Precious metals, in ounces per ton, from the Golden Fleece mine.

Class.	Gold.	Silver.
1	134.10	3,077
2	6.11	238
3	2.00	53
4	.40	15

The values in all the ores vary so widely that it is not possible to lay down any rule which will not have as many exceptions as it has instances.

SUMMARY OF ORE DEPOSITS.

The lodes of Lake City are fissure veins formed partly through the replacement of shattered and sheeted zones in the country rock and mainly through the filling of open spaces. They average between 500 and 1,000 feet in length, have a similar vertical range, and an average width of 10 inches to 5 feet. They show a wide range of strike and dip at steep angles. They consist of three closely related mineralogic types. The first contains pyrite, galena, sphalerite, and chalcopyrite with subordinate tetrahedrite, in a quartz gangue with some barite and rhodochrosite, and yield silver and lead with subordinate copper and little gold. The second contains galena, sphalerite, and tetrahedrite with subordinate chalcopyrite and pyrite, in a gangue of quartz, barite, and rhodochrosite, and yield chiefly silver and lead. The third contains petzite, tetrahedrite, and minor quantities of other sulphides, in a gangue of fine-grained quartz carrying some hinsdalite in places; this type yields silver and gold in proportion by value of 1:1 and is characterized by high values in both gold and silver.

The first two groups constitute the bulk of the Lake City lodes, as there is but one productive telluride vein. Their ores are low grade where unaffected by surficial alteration, the major portion of the Lake City production coming from ores enriched by secondary sulphide enrichment that has produced chiefly pyrargyrite as a secondary mineral. Oxidized ores are widely distributed. Lodes are, for the most part, separated by considerable areas within which no veins have yet been located, the Capitol City group being the only closely spaced series of veins exploited.

The Lake City lodes comprise the northeastern portion of the mineralized area which includes Rico, Telluride, Silverton, and Ouray. The lodes show great similarity to those of these areas, but were probably formed under a slightly less cover of overlying rocks.

The lodes are later than all of the rocks exposed in the region except the rhyolites and basalts of post-Potosi age and are hence of late Miocene or early Pliocene age. They are believed to have been derived from the vapors emitted from a magma of monzonite whose apophyses as intrusions are scattered through this general region in considerable numbers.

FUTURE OF THE DISTRICT.

The Lake City district possibly contains (p. 44) unworked and undiscovered veins that are similar in mineralogical character to those already developed, and it is on these, combined with the careful mining and milling of the ore from the veins already located, that the future of the district depends. A quantity of low-grade ore is now in sight, associated with which is an enormous amount of zinc blende. This ore may perhaps be treated with profit if the proper kind of concentrating works are erected, and the zinc may also be sold if mechanical means can be successfully used in its separation from the commonly associated minerals.

As the geology of the region has so little apparent connection with the deposition of the ores (p. 46), it is impossible to lay down any rule as to the best places to look for new bodies of mineral. The richest mines are in the andesite of the Picayune volcanic group, but veins found elsewhere in the district have the same general mineralogic content, so that no inference can be drawn from the occurrence in this particular andesite.

The fact that some of the veins can be traced on the surface for considerable distances would seem to point to the general conclusion that the extension of some of the already profitably worked veins may be found by a careful study of the topography and the relation of the veins to it, taking into consideration their dip and strike. On the other hand, as it is rather evident that the district contains mainly only the roots of veins, it would probably be more profitable to look for new discoveries rather than the extension of those already worked, as doubtless the major part of these have been eroded away, leaving only their lower parts.

An interesting feature is the date of the location of the properties which have proved to be successful producers. Without exception the veins which have paid were located in the early days of the mining activity. A great many prospects have been abandoned which show surface croppings just as promising as those of some of the paying properties. Much of the loss that has been sustained in mining in this district has arisen from unjustifiably excessive initial expense. There have been some startling examples of reckless expenditure in the district, which tend to weaken the confidence of the mining public and to destroy any chance of obtaining funds for judicious exploitation.

MINING CONDITIONS.

POWER.

Until recently a majority of the large mines used coal for the generation of power. Lately a few dams have been erected and water power utilized for the generation of electricity for the Hidden Treasure, Moro, and Lellie mines. The first two take water from Henson Creek and the last named from Nellie Creek.

The steep gradient in most of the streams makes it easy to obtain the head necessary for hydroelectric installations in a region of limited water supply. An objection, however, to this means of generating power is the low temperature which prevails during the winter months, at which time the streams throughout the mining district are frozen over. A means of obviating this difficulty is to build a dam at such a place that quite a deep body of water may be obtained, so that when the surface freezes there will be enough water below the crust of ice to furnish the requisite flow. The Hidden Treasure dam is said to be 100 feet in height. The natural conditions of the banks of the stream are admirable for such a dam, and a great supply of water can be maintained.

The officers of the Moro mine state that sufficient water is available to operate the mine during the entire winter, although they think it is doubtful whether they can generate enough power to operate both mine and mill during the months from December to May.

In all probability it would not be possible to obtain water during the winter months from any of the tributaries of Henson Creek, they being frozen solid during the cold season.

The large mines using coal for the generation of power have been the Ute, Ulay, Golden Fleece, Black Crook, and until 1907 the Moro. They have obtained their fuel from Crested Butte, Colo., when possible, and from Somerset, Colo., when the Crested Butte coal was not to be had. Run-of-mine coal sold at the time of writing (January, 1909) at $2.50 to $3 a ton on the cars at the mine, and lump coal at $4.50 a ton in carload lots on the cars at Lake City. Run-of-mine coal is said by some to be very unsatisfactory, but the lump coal is said to be about the most satisfactory in Colorado for steaming purposes.

Gasoline has been used at the Pelican property, but the foundation failed to withstand the vibrations of the engine and further use of the machine was temporarily abandoned. The company intends, however, to place the engine on a firm foundation and resume its use. Gasoline costs 16 cents a gallon in barrel lots on the cars at Pueblo, Colo., and that used by the Chicago Tunnel Site Co. is reported to have averaged 58° to 65° hydrometer test, each shipment, however, showing considerable variation. The Pelican at one time contracted with the Lake City power plant to deliver electricity at the mine. After having erected the line, however, it was found that the company was unable to furnish enough power to run the mine and the scheme was abandoned.

LABOR.

The labor conditions in the Lake City district have been very uniform and the differences between operators and laborers have been slight. When there has been great activity in the region it is understood that labor has been easy to procure. The wages paid are about the same as elsewhere in the San Juan region, ranging from $3 to $5 per day, according to the class of work.

MINING METHODS.

The early work on most of the veins was carried on through drifts driven on the veins. The adit tunnels run were short and easily operated. This was very advantageous during the early stages of exploitation, when the deposits were easily accessible. As depth was gained, however, long crosscut tunnels became necessary and these have almost invariably proved disappointing. The Vermont tunnel, T. C. M. tunnel, Lucky Strike tunnel, Hidden Treasure tunnel, and many others have been started, but so far none have had satisfactory results. Most of them have not gone as far as they had intended to go at the outset, as the character of the vein encountered in depth did not seem to justify the outlay.

No deep vertical shafts are used in the mines, although several properties have developed the veins by inclined shafts following the general dip of the vein.

The ore is transported from the mines by burros, wagons, or wire-rope tramways. The last named are used on the Hidden Treasure, Lellie, and Moro properties to connect the mines with the mills located several hundred feet below the mine openings and from a quarter to three-quarters of a mile distant.

EXTRACTION OF METALS.

From the beginning of active mining operations in the Lake City district there have been smelters and lixiviation plants, which, between them, have treated much of the ore from the Lake City district and some from the Silverton district with more or less success. Because of the historic interest connected with the early operations in the milling and smelting of the ores from this region a few lines will be devoted to that subject.

On October 31, 1877, the Ocean Wave smelter turned out its first lot of base bullion, about 10,000 pounds. The works were equipped with two roasting furnaces and one stack and had a roasting capacity of about 15 tons a day. First charcoal and later coke from Trinidad[1] was used for fuel. Crooke's smelter was also in operation at this time, although details of its equipment are not at hand. It is said to have shipped 300 tons, worth $48,000, during the year 1877.[2] Its slag dump is reported to have been twice reworked with profit. The Van Gieson Lixiviation Works were in successful operation at an early day and are reported to have had an output of $35,000 in silver bars during the fall of the year 1877.[2] The product ranged from 850 to 925 in fineness.[1] Other smelters and other lixiviation plants existed, but a description of them would be of no real value. The only smelter not partly dismantled in the Lake City district in 1909 was the one under construction by the management of the Lake City Mining & Smelting Co. It will have a 100-ton coke furnace, 40-horsepower boiler, 35-horsepower engine, dynamo, 110 volts direct current, blower with 1-pound per square inch pressure, crusher, rolls, grinder, and assay office.

[1] Eng. and Min. Jour., vol. 24, 1877, p. 369.

[2] Idem, vol. 25, 1878, p. 62.

The smelters which have received most of the ore from the Lake City district have been the Omaha and Grant smelters of Denver, Colo., the Eilers plant at Pueblo, Colo., and the Ohio and Colorado smelter at Salida, Colo. At times other smelters in the State have received consignments from this area, but the majority has gone to the above-mentioned plants. The freight charges per ton would probably average from $5 to $8 to Salida and Pueblo. The treatment charges plus the cost of mining and shipping will run from $10 to $15 a ton in the Lake City district, so that under existing mining conditions it will hardly pay to work smelting ore running under $20 per ton. With concentration, however, a much lower grade of ore can be mined and milled with profit. The Hidden Treasure, for example, mined and milled $9 ore at a profit. The Golden Fleece milled $12 ore, saving 65 per cent of the value, at a total cost for mining and milling of probably less than $5 per ton.

On the other hand, the processes employed by some of the mills have not proved to be suited to the kind of ore treated, and a large part of the valuable metals was carried into the tailings, several tailing dumps having been worked at a fair profit by various means of lixiviation. The tetrahedrite, most of which is argentiferous, has a specific gravity of only 4.5, and when treated with galena, whose specific gravity is 7.5, it is lost by the same process which saves the lead sulphide. Galena is less brittle than tetrahedrite and does not slime so readily, so that after the ore is crushed and sent through sizers to the tables the galena is easily separated from the rest, and the gray copper, being brittle and of rather low specific gravity compared with the commonly associated minerals, is either left in close association with the gangue or is largely lost in the slimes.

DETAILED DESCRIPTIONS OF MINES.

CAPITOL CITY GROUP.

GALLIC-VULCAN.

The Gallic-Vulcan claims are located on the south side of North Fork of Henson Creek, at an elevation of 10,300+. A good wagon road from Capitol City, about a mile distant, leads directly to the properties. Two patented and six unpatented claims comprise the group.

History and production.—The Vulcan was discovered in 1883 and the Gallic a few years later. The development on the claims has been done almost entirely by Benjamin Guionneau and his relatives, who have at no time employed large shifts or carried on extensive operations. The development is the result of the work of a few men continued over a long period of years.

The total production of the Gallic and Vulcan mines is small. The ore treated has been hand sorted so that no general average of the run-of-mine ore can be obtained. The concentrates produced by a small mill installed on the ground are said to have contained about 0.21 ounce gold, 10 ounces silver, 50 per cent lead, and some zinc and iron.

Development and equipment.—The Vulcan property is developed by an adit tunnel driven about 800 feet to cut the Vulcan vein. A vein, thought to be the Vulcan, was cut about 600 feet in, but not enough work has been done on it to prove its identity. A shallow discovery shaft has been sunk.

The Gallic mine has a crosscut about 820 feet long, which cuts two veins. The first is about 675 feet in and is possibly a continuation of the Vulcan vein; the second is 140 feet farther in. There has been about 1,000 feet of drifting and some stoping on the first vein. On the second vein there is only about 140 feet of work and no stoping.

Most of the ore in the veins has been hand picked. As the quartz is very sugary, the use of powder is unnecessary.

The equipment of the plant consists of a small concentrating building, connected by trestle with the ore house. It contains an old boiler, 40-horsepower engine, table, 1-compartment jig, 2-size screen trommel, one sizer, one elevator, one set of rolls, one crusher, and a small ore bin. From the crusher the ore is raised to a double trommel. The ore which does not go through the first screen is sent to a set of Cornish rolls and thence back to the screens. The fine material goes to the table and the coarse to the jig.

Country rock.—The country rock at the Gallic tunnel is mostly andesite of Silverton volcanic series, which in places contains quartz and hence might be classed as a dacite. At the first vein in the Gallic tunnel the country on one side is andesite and on the other quartz monzonite porphyry. The vein at one place is in the former rock and at others in the latter.

Veins.—The fissure in which the vein occurs shows movement both prior and subsequent to the introduction of the vein material. Surfaces of galena show striations produced by attrition, much movement being noticeable throughout the vein.

The ore shoot is irregular, being wide in some places and almost pinching out entirely in others.

In places the vein contains solid masses of galena several inches wide, but these are not persistent and no definite idea of the actual size of the ore body is obtainable.

The dip of both the Gallic and Vulcan lodes is southwest, the former about 60° to 80° and the latter 50°. The strike of both is N. 7° to 15° W. The trend of the veins is in general rather constant, although numerous marked local changes appear in the workings.

Ores.—The ore comprises galena, sphalerite, pyrite, chalcopyrite, gray copper, hessite, sylvanite, native silver, native tellurium, and native gold, and the gangue, quartz, barite, calcite, some kaolin, and a little fluorite and apatite, the relative abundance being in the order named. The first three ore minerals are by far the most abundant, and quartz probably composes nine-tenths of the gangue.

The quartz is almost universally sugary and full of cavities, many of which are due to the solution of crystals of calcite, barite, or gypsum. Within the cavities in the altered country rock crystals of apatite and fluorite occur with pyrite and sphalerite. Both the ore and gangue minerals show remarkable crystallization. Some tellurides occur in the quartz and a few in thin seams in the country rock near the vein. The native gold has been found in association with tellurium and sphalerite, in places as a partial coating over these minerals.

The original vein was probably a small one of quartz carrying galena, sphalerite, pyrite, and tetrahedrite. Subsequently the vein and the country rock in its immediate vicinity suffered severe deformation and very thorough brecciation. Next the fragments of country rock and vein were cemented by quartz carrying pyrite, galena, sphalerite, chalcopyrite, tellurides, free gold, and silver. This second deposition of quartz and ore minerals did not completely fill the cavities, however, and the resulting vein is spongy and porous throughout.

The wall rock has affected the mineralization slightly, if at all. The first vein in the Gallic tunnel occurs partly in andesite and partly in monzonite porphyry, but neither exerted any noticeable influence on the ore deposit.

The depth of oxidation is probably between 400 and 600 feet. Lead carbonate has been found in the Vulcan crosscut 400 feet below the surface, but none, it is stated, was found in the Gallic workings, which are located about 300 feet below the Vulcan.

EXCELSIOR.

The Excelsior mine is owned by Frank Adams and W. B. Owen, both of Capitol City, Colo., who work the property themselves. It is located on the slope just north of Capitol City, at an elevation of 10,220 feet, and may easily be reached by wagon road. The ore has to be hauled by wagon about 9 miles to Lake City, Colo. The work is all done by hand.

History and production.—The Excelsior was located in 1878 and patented in 1889. The first shipment, made in 1893, consisted of two cars, which brought returns of $65 a ton, averaging 59 ounces of silver and 10 to 12 per cent copper. In 1895 and 1896 shipments were made of about 200 tons, which averaged $65, running about 50 to 59 ounces silver, 11 to 15½ per cent copper, and 5 per cent lead.

From 1896 to the present time (October, 1908) from one to five cars a year have been shipped.

Development.—The workings consist of a crosscut of about 100 feet to the vein and a drift of 500 feet along the vein. Some 200 feet in on the vein the original discovery shaft connecting the mine with the surface is cut. This shaft is no longer in use, the ventilation of the mine being accomplished through the Broker, a contiguous property whose drifts connect with those of the Excelsior on the main level. Above this level considerable work has been done in a stope which extends up about 160 feet and is in general between 90 and 100 feet long. The material taken out of this stope by the Broker and Excelsior companies would amount roughly to 64,000 cubic feet. A smaller stope is located just south of the main large stope above the first level. Below the main drift is a shaft about 106 feet deep, off which short levels have been run, and a body of approximately 75 by 30 by 3 feet has been stoped out. Practically all of the work was carried on in this mine by overhand stoping, the ore and rock being sent down through two mill ways to the main level, and then trammed out in cars, the selected ore going direct to the ore bin and the rest being distributed over the dump, according to its content of gangue and country, into second and third class ore. The country rock broken has been utilized in a large measure to fill the stopes.

Country rock.—The walls are entirely Eureka rhyolite, which shows considerable alteration in the immediate vicinity of the vein and is rather highly impregnated with pyrite. That there has been movement since the beginning of vein filling is evidenced by the inclusion in the vein matter of small pieces of country rock, on either side of which ore minerals occur. The vein as a whole, however, is tightly frozen to the walls.

Veins.—The ore body itself occupies an ordinary fissure and seems to be rather regular in size, averaging perhaps 9 inches in width, and is fairly continuous throughout the workings. In places it is much narrower and elsewhere plays out entirely, leaving only the barren vein. The vein dips 60° to 70° N. 80° E. and strikes in a general direction of N. 10° to 12° W. In the upper workings the dip is more pronounced, approaching the vertical toward the top of the upper stope.

Ores.—The ore minerals are sphalerite in large quantities, a good showing of chalcopyrite (usually occurring with sphalerite) in the upper parts of the mine, some galena, a little gray copper, and much pyrite. According to the owners, 150 pounds of native copper was found 400 feet in on the main level and some native silver was found below the level. Native silver is said to become prominent in the lower workings, where sphalerite predominates. In the orkings, the top of which is only about 40 or 50 feet below the surface, small quantities of azurite, malachite, and some limonite occur.

Quartz is the only gangue mineral present, the absence of others commonly found in the region being notable. On the main level sulphate of copper is forming on a small scale.

The ore is sorted in the ore house and shipped as first, second, and third class ore direct to the smelters. It is the aim of the operators to ship ore containing at least 39 per cent zinc, so that they will receive returns for this, as well as the lead, silver, and copper.

CZAR.

The Czar mine is now owned by Julius Seymour, of New York, but most of the development on the property was completed prior to his ownership. It is located about half a mile from Capitol City on the eastern slope of Yellowstone Gulch at an elevation of 10,800 feet above sea level and may be reached by wagon road. At present (October, 1908) it is not in operation.

Production and development.—It is reported that two cars shipped to Canon City yielded 22 per cent lead, 26 per cent zinc, and 3 per cent copper, 9 to 14 ounces silver, and $3 gold to the ton. A third car is said to have averaged 39 per cent zinc, 14 per cent lead, 3 or 4 per cent copper, and $3 gold to the ton. In 1904 a small car of galena averaged 42 per cent lead. As the smelters would not pay for both lead and zinc and the sorting of the two ores cost so much it was found that the shipments were unprofitable.

The development work on the property consists of two levels supposed to be drifts on the same vein, and a shaft connecting the upper level with the surface and extending down 120 feet to a junction with an upraise of 100 feet from the lower level. Above the upper level some stoping has been done, over 7,800 cubic feet of rock and vein material having been extracted up to October, 1908; there is also a small underhand stope about 10 feet deep and 30 feet long just beyond the shaft.

Country rock.—The country rock is Eureka rhyolite, which shows little or no alteration a very short distance away from the vein and in all probability has had slight influence on the ore bodies.

Some faulting was observed in the Czar mine and gouge and a small horse of country rock were seen in the breast of the lower level. The whole vein has been pretty well shattered.

Veins.—The ore body is a fissure vein of pyritic lead-zinc ore. The veins comprising it are two in number, one of which is worked in the upper level and the other in the lower. Both are small veins, not over 2 feet wide in any place; the average "ore course" is not more than 3 inches wide, though in places it measures 8 inches and in others narrows to ½ inch. Several small and apparently unimportant veins were seen in the breast of the lower level.

Contrary to the general trend in the district, the vein in the upper level strikes about 6° NE. and dips from 60° to 80° E. The main vein in the lower level has a general northerly strike, with approximately the same dip as that in the upper level. However, its course is quite irregular and no definite direction can be given to it.

Ores.—The ore minerals consist of galena thickly interspersed with sphalerite, the whole frequently cutting through a thin layer of chalcopyrite. Pyrite is a common associate of the quartz, which is the only gangue mineral found. Sphalerite and lead sulphide are about equally abundant and are very intimately associated. All of the ore minerals except the chalcopyrite are fairly well crystallized, but the quartz is almost entirely massive. Probably the chalcopyrite was deposited first, followed by the sphalerite and the galena, the whole being cemented together by quartz and pyrite, which no doubt crystallized contemporaneously.

CAPITOL CITY.

The Capitol City mine is located on the west side of Yellowstone Gulch at an elevation of 10,600 feet and may be reached by wagon road from Capitol City, about a mile distant.

The property has three levels, supposed to be on one vein, which probably extend altogether over 1,700 feet. The actual distance can not be given with accuracy, as the mine was in poor condition at the time of examination, and the uppermost level "caved," so that examination was impossible. Considerable stoping has been done in the mine, especially above the lower level. A mill, called the Capitol City mill, was operated in connection with this mine. It was equipped with a boiler, engine, crusher, rolls, and four jigs. In 1900 this mill was torn down.

The Capitol City ore body is in andesite belonging to the Silverton volcanic series, which shows considerable alteration along the vein. The feldspars are largely changed and the hypersthene crystals are almost entirely gone. Some chloritization is noticeable and a great deal of pyrite is present in the rock. The rock is a lava flow, as are most of the eruptives in the district, and has been more or less disturbed by minor faulting in the vicinity of the vein.

The ore body is similar in many respects to those of the Czar and the Excelsior and may be classed with them. The fissure is clearly defined and fairly constant in direction. It branches or splits up, as shown by the vein in the lower level, which divides after going in about 300 feet. The ore body proper varies in width from

9 to 12 inches and the vein from 6 inches to 2 feet. The strike of the main vein is N. 20° W. and the dip about 80° NE. The western branch of the vein, which splits in the lowest level, is probably the one worked in the middle level. It strikes N. 40° W. and dips about 70° N. 45 E. This branch vein seems more clearly defined and more persistent than that in the lowest level.

The minerals found in the veins are sphalerite, galena, pyrite, and some chalcopyrite in a gangue composed almost entirely of quartz. There are several stages of deposition of the quartz, which is mainly in the massive form, though in many places sugary and in some showing distinct crystal outlines.

YELLOW MEDICINE.

The Yellow Medicine mine is located in Yellowstone Gulch 10,750 feet above sea level and may be reached by wagon road from Capitol City, about 1½ miles distant.

Previous to 1896 the production, as given by the mint reports, amounted to approximately $40,000, the greater part of the value coming from silver and about one-eighth from the copper. The production before 1892 and after 1896 is unknown, but during 1896 Crow & Fagan, according to report, shipped 500 tons from the middle level. In 1898 the Yellowstone Mining Co. is said to have shipped concentrates for about three months. In 1907, under bond and lease, O'Brien, Bowles & Bardwell for a time mined and shipped, crude, 15 tons mill dirt a day to the Moro mill. It is reported that the runs through the Moro mill were successful until the price of copper declined. The Moro shipped the results of their treatment as concentrates.

The workings of the mine consist of three levels. Only the upper one was accessible at the time of visit; the middle one was caved at the entrance, and the lower one half filled with ice for 200 feet, beyond which a cave in the roof made further exploration impossible. As a consequence the data contained in this report have been obtained from the upper level, the ore bins, and the dumps. A mill was located just below the lower level and a blacksmith shop on the middle level. The mill was built and started to run in 1897. It contained a boiler, engine, crusher, 3 sets of rolls, revolving screen from each roll, set of revolving screens which went to four Harz jigs, and three buddle tables.

The vein occurs at the contact of a monzonite porphyry intrusion in a pyroxene andesite flow. The latter is very much altered along the contact of the vein and is recognizable only by careful examination.

The ore body occupies a simple fissure. In the upper level it dips 79° N. 70° E. and strikes N. 13° W.

The minerals found in the vein are galena and sphalerite in large quantities (the former predominating), pyrite, and chalcopyrite in a gangue of quartz with a very small amount of barite. In places the galena is very well crystallized in cubes, but much of it is steel galena in large bunches.

LILLY.

The Lilly adit, located at an elevation of about 10,500 feet, was full of water at the time of investigation. It is said that ore has been shipped to the Capitol City mill for concentration, but the results are not definitely known.

CHORD EXTENSION.

The Chord Extension is located at 10,800 feet elevation on the east side of Yellowstone Gulch. Development work consists of a shallow shaft, a crosscut to the vein, and a drift on the vein. Not much stoping has been done. The vein is in monzonite porphyry and is in few places more than 4 inches wide, the ore course varying from ¼ inch to 2 inches. The vein dips 75° N. 75° E. and strikes N. 10° W. According to report all the ore shipped was taken out when the shaft was sunk.

The minerals are tetrahedrite and galena, with some chalcopyrite in a gangue of barite, some quartz, and a little fluorite. The vein shows inclusions of silicified country (?) and some pure hematite. Slickensided surfaces are numerous in the country adjoining the vein, but the vein itself seems very tightly frozen to the walls. There appears to have been first a deposition of chalcopyrite, tetrahedrite, and galena, with a gangue of quartz, followed by movement which disdistorted the vein and a second deposition of minerals in a gangue of barite.

WOODSTOCK.

The Woodstock prospect is located in Yellowstone Gulch at an elevation of 10,100 feet. It is owned by Mr. Whinery, of Lake City, who reports that he shipped 200 pounds in 1895 which brought him $300; almost all of the value came from gold, which is said to have been found native in wire form about 40 feet down the shaft. The developments consist of a shaft 225 feet deep and an adit 75 feet long. These are in pyroxene andesite which shows some little mineralization by pyrite a short distance from the vein. The vein itself contains brecciated fragments of country rock and is made up of a gangue of quartz, with galena, zinc blende, chalcopyrite, and pyrite, in relative amounts corresponding to the order mentioned. The vein is tightly frozen to the wall and varies from 2 to 6 inches, widening as it descends. It dips 70° to 80° N. 70° E. and strikes N. 15° E.

OTTAWA.

The Ottawa prospect is located just above the Woodstock in the same country rock. A thin vein of quartz shows some mineralization and is supposed to have produced 2 or 3 tons of lead ore, which, according to report, were shipped from the vein near the surface in the summer of 1907. The vein dips N. 73° W. and strikes N. 10° E., and has been drifted on for 150 to 200 feet.

TOBY.

The Toby is located a short distance above the Ottawa and has been prospected for 150 to 200 feet by a drift on the vein. The vein, which is mineralized chiefly by oxidized iron ores, strikes N. 17° W. and dips 70° N. 80° E.

SILVER CHORD.

The Silver Chord property is located on the east side of Yellowstone Gulch at an elevation of 10,700 feet in country rock similar to that of the Czar mine. The workings consist of a shaft said to be 80 feet deep, which, at the time of the investigation, was practically full of water. As shown by the inclination of the shaft the vein dips 78° S. 60° E. and strikes S. 10° W. From the appearance of the outcrop the vein is 6 to 18 inches wide and has an ore course from 1 inch to 3 inches wide. The gangue is quartz and the ore minerals are galena, sphalerite, chalcopyrite, and pyrite, an association common to many of the mines and prospects in this gulch. Some ore is reported to have been shipped from this property.

CZARINA.

The Czarina is a small prospect in Yellowstone Gulch just west of the Czar mine. The shaft on the property is said to have been 25 feet deep; rock débris, however, has filled one-third of this. A small open cut on the vein shows it to contain about 2 inches of quartz with no appreciable ore body.

Eastward, across the Czarina property, three small veins outcrop with strikes of N. 6° E., N. 10° E., and N. 6° E.

LUCKY STRIKE TUNNEL.

The Lucky Strike adit tunnel, owned by D. M. Jameson, of Capitol City, Colo., has been run in hopes of cutting in depth the Excelsior, Czar, and other veins worked higher up. The total work done is far in excess of that needed to gain the distance desired. In all over 900 feet of crosscutting has been done to reach a point which could have been reached by 600 feet of straight-ahead work. The crosscut encountered several veins, but they show little or no mineralization.

They had the following dips and strikes in order, from the entrance in: Dip 75° N. 15° W., strike N. 73° E.; dip 83° N. 75° E., strike N. 10° W.; dip 70° S. 10° E., strike N. 80° E.; dip 79° S. 65° W., strike N. 23° W. The last one was practically at the breast of the workings, and the others were approximately one-fourth, two-thirds, and three-fourths of the way in.

The workings pass through Eureka rhyolite for 20 feet, pass a small dike of very much silicified rhyolite, penetrate 120 feet of Eureka rhyolite, cut andesite for a short distance, and pass into monzonite porphyry which prevails for about 500 feet. Then the crosscut swings sharply to the east and the rock becomes characteristic Eureka rhyolite to the breast.

Mr. Jameson has started another crosscut about 250 feet east of the present site to intercept the veins of Yellowstone Gulch properties, and at the present writing (1908) this is in 80 feet.

HENSON CREEK MINES.

The mines of Henson Creek are scattered along Henson Creek from a point about three-fourths of a mile west of Lake City as far as the narrow canyon just west of Capitol City. They are described in order from west to east.

PRIDE OF AMERICA AND BIG CASINO.

A shaft about 60 feet deep has been sunk on a small vein in a gulch which heads south from Henson Creek a little west of the Red Rover mill. It is 500 feet above the creek bed and about 10,000 feet above sea level. Two veins are disclosed in this shaft, a main vein 2 feet wide dipping 60° S. and striking nearly east and a smaller vein striking N. 45° E. Both veins carry galena-freibergite ores, with subordinate sphalerite and but little gangue. The galena appears to be the earlier mineral, as it seems to be broken with areas of silver-bearing tetrahedrite (freibergite) scattered through it. The freibergite is the most valuable mineral and carries very high values in silver; the galena, where unmixed with other minerals, averages only about 12 ounces or less per ton in silver. The assays on this ore showed, according to the owners, from 200 to 412 ounces of silver per ton—a statement which merits belief, as the ore contains a very large quantity of freibergite, which in nearly all of these ores is the silver-bearing mineral.

LELLIE (RED ROVER).

The Lellie mine is located on the north side of Henson Creek, about 1 mile west of the mouth of Pole Creek, on the steep bluff that rises abruptly for 2,500 feet above the bed of the creek. The upper and lower workings (fig. 7) are reached by wagon roads connecting with the main road in the bed of Henson Creek. The mine is now operated by the Planet Mining & Milling Co.

Production and development.—The Lellie has never been a very heavy producer. From the upper levels it has produced some ore, which, according to the management, was high in grade. The mint reports[1] show that in 1899 it was one of the important producers, yielding from the upper stope four cars of ore per week, which netted about $800 per car; but as the amount of stoping is small and it receives no specific mention in previous or later years, its active production seems to have been confined to that year. At the time of examination (1904) and since that time it has been

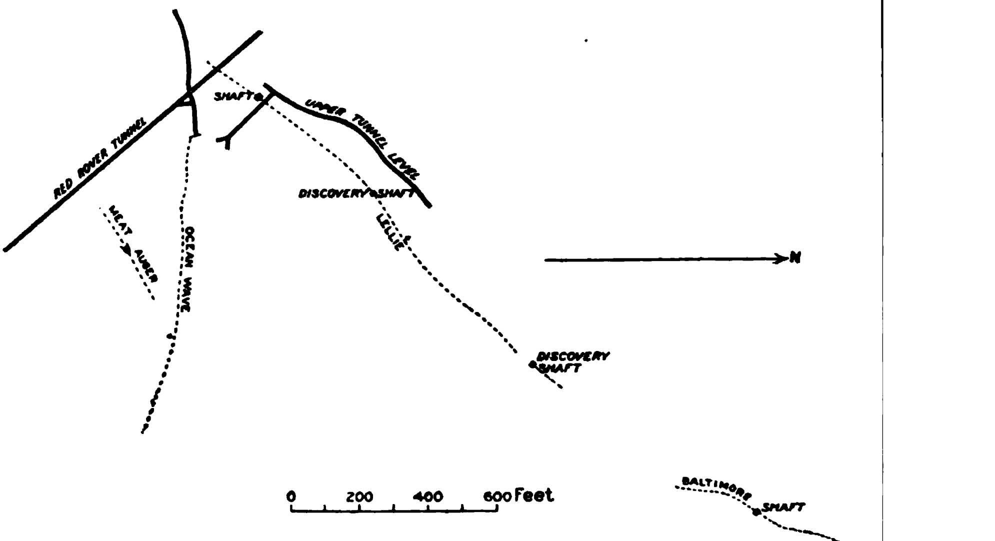


FIGURE 7.—Workings and outcrops of veins of Ocean Wave and Lellie (Red Rover) mines.

only intermittently worked. It was first opened by the upper crosscut in 1897.

The mine is fully equipped with accommodations for miners, shops, and a 50-ton concentrating mill, situated next to the main road in the bed of Henson Creek and operated by electricity. Water power is furnished to the mill by a 2-foot pipe line 3,700 feet in length, with a head of nearly 400 feet.[2] A wire-rope tramway connects the mine with the mill.

The vein is opened by two crosscut tunnels. The upper, which was the first driven, is a short N. 43° W. adit 200 feet long at right angles to the strike of the vein; the lower tunnel, which is 500 feet below at an elevation of 9,650 feet above sea level and about 260 feet above the bed of Henson Creek, is 1,140 feet long and taps the main vein in

[1] Report of the Director of the Mint for 1899, p. 112. [2] Rept. State Com. Min. for 1901-2, p. 92.

its far end. Drifts have been driven northeast on both levels for about 700 feet. These two levels are connected by a raise 500 feet high (vertical), from which three intermediate levels, separated by vertical distances of 120 feet, have been begun. Little drifting, however, has been done on them, as the vein was uniformly low grade and narrow. Some crosscutting and exploration on two parallel veins lying south of the main vein have apparently been unsatisfactory.

Here, as elsewhere in the district, the stoping near the surface and the high grade of the ore there encountered have led to the driving of a long (1,140 feet) crosscut for a vein which, when cut, failed to meet expectations.

Country rock.—The country rocks of the veins belong to the Picayune volcanic group, which consists, as stated by Mr. Cross, of layers of volcanic flow breccias, both andesitic and rhyolitic, whose rude stratification is well shown in the Red Rover crosscut tunnel. These beds vary in dip from a comparatively slight northerly inclination to one of 45°. For the most part they are less steep than the veins, but they seem to have influenced the formation of these to some extent. The veins steepen up in places and run parallel to the layers of breccia, giving the impression that they are replacements along especially favorable beds. At the far north end of the tunnel the sheeting planes of the vein coincide with the stratification of the Picayune volcanic group (which dips 45° N.), making recognition of the true character of the vein difficult.

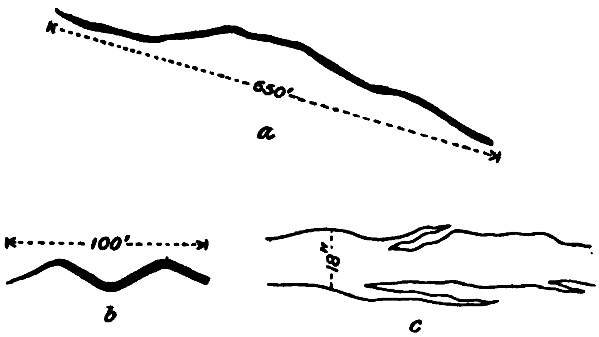


FIGURE 8.—Irregularities in the Lellie fissure along the strike. *a*, Plan of vein in long drift; *b*, plan of vein in short drift; *c*, plan of small portion of vein, showing irregular branches.

As replacement has for the most part been subordinate to the filling of openings, the wall rock seems to have exerted but little effect on the deposition of the ore, but until the different rock masses that make up the Picayune volcanic group have been carefully platted and mapped, the actual relations can not be stated with certainty.

Veins.—The Lellie veins are little if at all disturbed by faulting. The ore deposits mined are typical fissure veins. Replacement here, as elsewhere, has been subordinate, but is more marked than in most of the veins of the region. In the upper workings, where for 400 feet the vein averaged from 1 foot to 4 feet in width, it has fairly well-defined walls frozen tightly to the filling material, with little or no clay selvage present. In the lower workings the vein is much more irregular, being generally only 8 to 14 inches wide or being broken up into a large number of parallel and intersecting stringers separated by irregular sheets of country rock. The vein dips about 60° NW., but in the bottom level is parallel to the stratification of the flow breccia, which dips 45° N. In strike also the vein is extremely irregular (fig. 8).

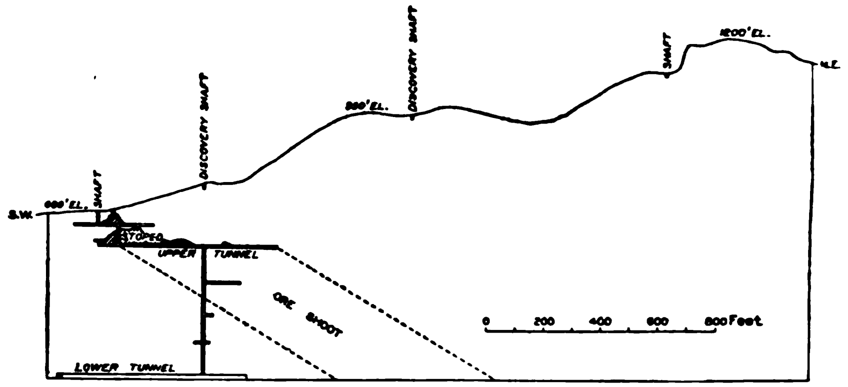


FIGURE 9.—Longitudinal section of the Lellie vein, showing position of rich upper stopes and inclination of the ore shoot. Elevations given are vertical distances above the lower tunnel level.

In detail the vein shows many angular inclusions of country rock, and is for the most part broken up into small irregular stringers, with intervening layers of highly altered andesite. It is difficult to compare the vein in the upper workings with that below on account of the inaccessible condition of the old abandoned upper portions of the mine; but it is probable that in this mine, as in most others in the district, the wide and fairly workable veins die out in depth into narrow and stringer-like roots that rarely pay for the added expense of deeper exploration and operation.

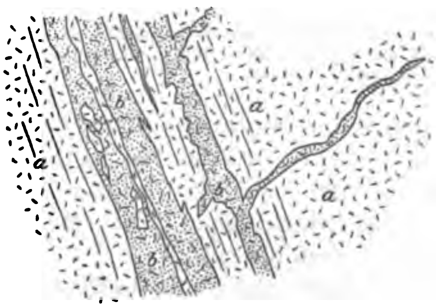


FIGURE 10.—Face of Lellie vein, showing irregularities of vein structure. *a*, Country rock with planes of sheeting; *b*, vein filling.

Ores.—The vein fillings consist of quartz, rhodochrosite, barite, pyrite, galena, sphalerite, and tetrahedrite, with some chalcopyrite in the workings below the first level. The galena, when abundant and massive, carries as high as 20 ounces of silver per ton, though it often runs below that; but the great bulk of the values lies in the argentiferous tetrahedrite, which is readily distinguishable by its greasy appearance. In places it is mixed with the galena and in places scattered separately through the gangue. Pronounced banding is to be seen here and there.

Some of the ore that carries chalcopyrite runs well in gold, but otherwise the gold content is not noteworthy. The high-grade ore from the upper levels consisted of an intricate mixture of argentiferous tetrahedrite and galena. The nature of the ore in these levels is not known, but it is reported to have carried high values in silver and, locally, in gold.

Some of the ore, consisting chiefly of freibergite, averages per ton: Silver 200 to 1,000 ounces, value $500;[1] copper 12 per cent, value $33; gold 1.5 ounces, value $30; a total value of $563.

The longitudinal section of the vein (fig. 9) shows that the ore occurred in shoots which pitched 30° NE. along the strike of the vein. These were separated by barren areas in which the gangue of quartz predominated and the metallic minerals were relatively less abundant. The shoots had a stope length of about 250 feet. The rich ore all occurred in stopes which were near the surface and well within the zone of secondary sulphide enrichment. Figure 10 shows some irregularities of the vein structure.

VERMONT.

The Vermont mine is located on the west side of El Paso Creek about half a mile north of Henson Creek. It is one of four claims, the Scotia, Vermont, Ocean Wave, and Wave-of-the-Ocean, that lie end to end in a S. 75° W. direction on what is in all probability the same vein (fig. 11).

Development and production.—The openings are at the base of a high precipitous bluff that forms the west wall of the creek, towering upward for 500 feet. A shaft 175 feet deep is reported but was not seen. The workings are about 10,000 feet above sea and about 500 feet above Henson Creek. A rough wagon road leads from the mine down to Henson Creek, where it joins the main road to Lake City. The mine is opened by a S. 65° W. tunnel into the bluff. The upper workings have been abandoned since 1899 and only this drift is now accessible, but the mine has in the past produced a considerable tonnage of ore. The high values found in the upper workings induced the management to attempt a long adit tunnel from Henson Creek to cut the main vein. This was driven in for 1,500 feet in 1899 at a heavy expense and was then abandoned.

The Vermont is one of the older mines in the Lake City region. Work on it has been abandoned since 1906. The production has been about as follows:

[1] Values figured on price of silver during years when mined and on tonnage shipped.

Production of Vermont mine.

[From mint reports.]

1884	$4,965.00
1887	40,436.00
1888	62,648.00
1892	6,993.00
1895	[1] 182.24
1896	[1] 119.60
	$115,343.84

The mine records for the same years show a production of $115,043.84.

Ores.—No data are available as to the mineralogical character of the ore from the Vermont mine, but as it is of the same general vein series as the closely associated veins of the Lellie, Wave-of-the-Ocean, and Ocean Wave, it undoubtedly consisted chiefly of argentiferous tetrahedrite and galena, with smaller quantities of sphalerite, chalcopyrite, and pyrite. The main output of the mine has been silver and lead. The value of the ore from the upper workings in 85 shipments of 25 tons each ranged from 33.9 to 253.10 ounces of silver, and 7.5 to 59 per cent lead. The average silver and lead content for these 85 shipments was 84.53 ounces of silver and 27.96 per cent lead, giving an average value, computed on the present market prices, of $44.80 silver and $12.06 lead, or a total average gross value of $56.86 per ton of ore mined. In 1894, 63 tons mined yielded $4,965, an average of about $79 per ton. Two later shipments of ore of 16,078 pounds and 10,504 pounds, in 1895 and 1896, respectively, yielded an average total value of $22.67 and $22.78 per ton each.

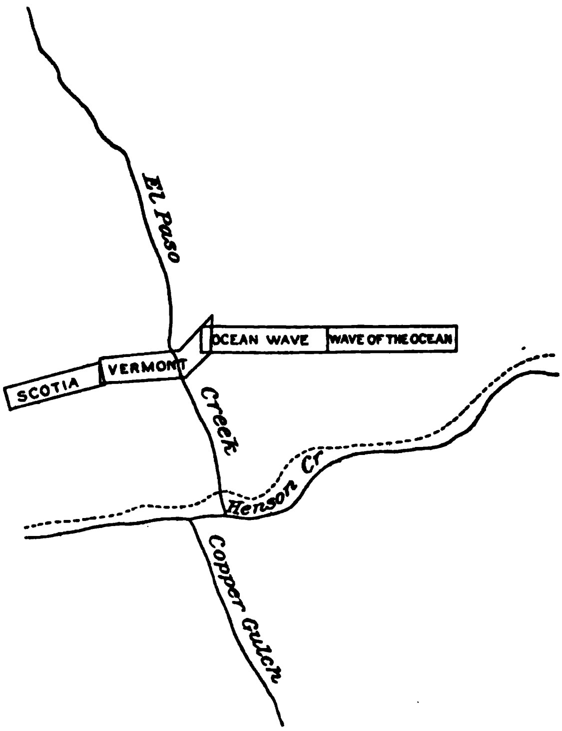


FIGURE 11.—Sketch of the Scotia, Vermont, Ocean Wave, and Wave-of-the-Ocean group of claims.

[1] Figures furnished by the company.

UTE AND ULAY AND HIDDEN TREASURE.

The most productive and also the most extensive workings in the Lake City region are those of the Ute and Ulay and the Hidden Treasure mines. The two, though operated by separate companies, are to be regarded as a single unit geologically, inasmuch as they are on the same vein or group of veins, and their workings interpenetrate one another. Plate V shows a plan of the underground workings and outcrops on the Ute and Ulay and the Hidden Treasure ground.

DEVELOPMENT.

UTE AND ULAY MINE.

The workings of the Ute and Ulay mine are located in and adjacent to Henson Creek, at the eastern extremity of the town of Henson, a settlement which has grown up in consequence of the operation of these mines.

Four veins have been extensively worked—the Ute vein, the Ulay vein, the Annie vein, and an unnamed vein cut in the new shaft. The earlier workings of the mine were on the Ulay vein, which crosses the bed of Henson Creek. Two short drifts above the creek on the north side enter directly on the outcrop of the vein, but these are not extensive, and but little mining has been done on them. The main working opening is an inclined shaft dipping northwest. From it nine levels have been run. The first three, called third, fourth, and fifth levels, are not extensive. The sixth is more extensive, but the seventh, eighth, ninth, tenth, and eleventh are the main working levels of the mine and from them the large production of the vein has been stoped.

All of these workings are in bad repair and the mine is full of water, so that no description of the Ulay vein can be given other than that furnished by those who have worked in it and operated it.

The workings of the Ute vein interpenetrate those of the Hidden Treasure to the northeast. The vein (Pl. V) lies about 500 feet northwest of the Ulay and is roughly parallel to it. It is opened only on the hill slope northeast of the Ulay shaft and has not been followed southwestward across the creek. It is opened by two crosscut tunnels to the first and second levels. The fourth level is opened by an extremely crooked adit running in from the hillside northeast of the Ulay shaft. The lowest level is entered by a long crosscut tunnel from a point 70 feet northeast of the Ulay shaft. From the most southwesterly point in the mine the workings extend to the Hidden Treasure line. Throughout the greater part of this distance the ground is stoped, only a few pillars of lean ore being left to support the roof. No stope maps or very reliable information could be secured about these workings and statements as to the ores can be based only on inferences drawn from the small amounts of ore still remaining.

At the northeastern end of the mine the Ute vein passes into the Hidden Treasure ground, the third level of the Ute being continuous with the fifth level of the Hidden Treasure.

HIDDEN TREASURE MINE.

The Hidden Treasure property includes the five claims, Hidden Treasure, Invincible, Protector, Don Quixote, and Crystal Crown. It

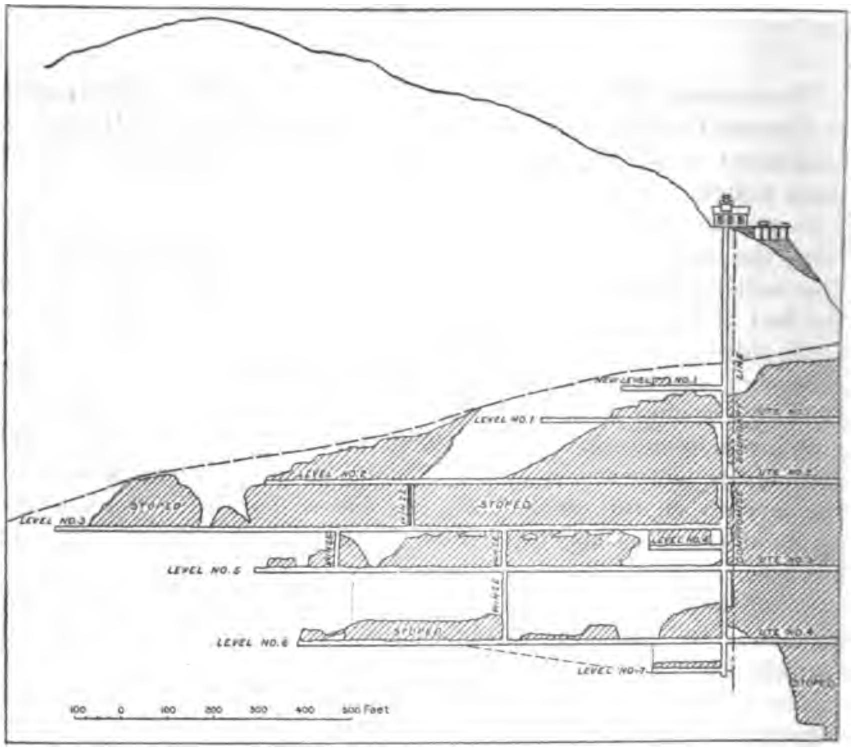


FIGURE 12.—Longitudinal section of the Hidden Treasure vein, showing the stopes and the pitch of the ore shoot.

is equipped with a 100-ton concentrating mill erected in 1898, a water-driven compressor, a 50-horsepower electric hoist, and a Bleichert wire-rope tram, with twenty-five 450 to 500 pound buckets, having a capacity of about 12 tons per hour, connecting the shaft with the mill.

The shaft was sunk on the vein for 265 feet before it encountered ore which paid expenses. The first ore was taken from the mine in June, 1897, and from that time until 1908 it has been worked almost continuously. During 1897 ore was shipped to the smelters, as the concentration plant had not then been erected, but since 1897 the bulk of the ore has been milled and concentrates averaging about $40 a ton have been shipped. Eight levels have been run from the shaft. (See fig. 12.) The vein has been stoped almost continuously from the fifth level to the surface.

The Ute and Ulay mine has been among the largest producers of silver and lead in Colorado, being reported to have yielded between $10,000,000 and $12,000,000 gross. This production takes no account of the poorly adapted milling plant in which much of the earlier ore was treated and by which it is estimated that a great deal of money was lost. The Hidden Treasure mine has produced upward of $700,000.

COUNTRY ROCKS.

The country rock in which the ore bodies occur is the Picayune volcanic group, which carries the largest number of valuable deposits in the Lake City region. This rock shows a great variety of texture and color, so that its identification in the several localities where the best-known mines occur would be impossible without painstaking geological labor in tracing it from one locality to another. Both the Ute-Hidden Treasure vein and the Ulay vein lie wholly within this rock, although at the northeast end the Hidden Treasure vein closely approaches the overlying Eureka rhyolite. In the deeper portions of the workings and in the mouth of the long adit tunnel where the rock is unaltered by surface agencies it has a dense grayish appearance, almost glassy in places. It is characterized by broken brecciated fragments, which are of the same nature as the matrix which incloses them and which were obviously formed during the flow of the rock as it cooled. The congealing crust was broken during the flow and the fragments submerged in the still molten portions, giving rise to a breccia in which no distinction can be made between matrix and fragments. The fragments are of all sizes, varying from almost imperceptible irregular flakes to those measuring many inches. The feldspars are small, though in places they perceptibly mottle the fresh rock. In the vicinity of the Ute vein the rock (see p. 44) has been profoundly altered, passing from gray to almost black, and the black giving way again, in the immediate contact with the vein filling, to a light green, which is chiefly due to the silicification which has accompanied the ore deposition.

Small fragments of country rock, when included in the ore, are generally entirely altered and no black cores are perceptible, but large fragments, which alteration has been unable completely to penetrate, consist of a light-greenish shell over a dark blackish core. The rock is brittle and rather easily ruptured, so that regular veins have formed in it (as in the breccia of the San Juan formation in the

Ouray district), whereas in other tougher types of rock, such as coarse even-grained andesites in the vicinity of Capitol City, the v are more discontinuous and constricted. Another consequence of weakness of the rock is the very large number of horses, or fi ments of country rock, found in the ore—perhaps as striking a ture of these Lake City veins as any observed.

ORE BODIES.

VEINS.

The ore bodies of the Ute and Ulay and the Hidden Treasure mi are fissure veins. They are distinctly the result of the filling of o fissures and represent only in minor degree a replacement of the rock. Silicification, as will later be shown, in many places aff the walls and included fragments of country rock, but metallifer minerals are confined to the filling material. Four well-defined v have been either partly or extensively explored on the property the Hidden Treasure and Ute and Ulay mines. (See Pl. V.) In order of their importance they are the Ute, the Ulay, the Annie, an unnamed vein encountered in the new shaft. A small and undeveloped vein known as the California should also be mention An adit tunnel 500 feet in length has been driven to intersect The Annie, the Ulay, and the new vein were, at the time of the vi entirely inaccessible to examination, so that little can be lear concerning them except from the mine maps.

UTE VEIN.

Strike and dip.—The Ute and the Ulay are the main veins expo on the property. The Ute has been by far the most productive a important of any vein in the district. It has been traced on the s face for a distance of 2,700 feet along the outcrop, from a po northeast of the Hidden Treasure shaft southwest to a tram ho just above the mouth of the third level tunnel of the Ute, 1,200 f north of Henson Creek. Beyond these two limits it has not yet be traced in either direction.

The vein, as explored in the workings, describes an arc of la radius, with the concave side toward the northwest (in the directi of dip). At the southwest end the strike is N. 46° E., in the cente is N. 37° E., and at the northeast end beyond the Hidden Treas shaft it is N. 19° E. The concavity of the outcrop is increased by shallowing of the dip in the center of the Ute workings. This is broug out on Pl. V, in which the different levels, which may be regarded contours, may be seen to close up at both ends and flare apart tow the center of the vein's course.

In detail the strike is irregular, as the vein shows many slig deflections in strike as well as in dip, in this respect resembling t majority of fissure veins. These deflections are rarely large; the greatest is that which shows on the third and fourth levels of the Ute mine, 325 feet north of the adit tunnel of the second level, where the vein diverges 45°, continuing so for 45 feet, and then returns to its original direction. In outcrop the course of the vein is much more sinuous and diverges to the north from the true strike on account of the steep and irregular nature of the topography which it intersects.

Sharp bends occur in the dip also, a fact amply demonstrated in the Hidden Treasure shaft, where the skip now descends vertically, then moves almost horizontally, and then again goes down at a very steep angle. The average dip is between 56° and 60° NW.

Movement.—No criteria exist by which to determine definitely how much differential movement has occurred between the walls of the vein. The variation in width where pinches and swells follow one another in the direction of dip and strike indicate that there has been movement, but that it has not been excessive. The vein is characterized by considerable brecciated country rock which is included in the vein filling, but the brecciation has taken place on a relatively small scale. The fragments of wall rock are generally separated from one another by considerable distances and no evidences of excessive attrition are present. Faulting has not seriously affected the vein. A few cross veins are noticeable, but they seem to be of the same age as the main fissure. This regular and uninterrupted character has done much to facilitate exploration and to make expensive dead work unnecessary.

Width.—The vein averages about 4 feet in width, but pinches and swells after the manner of most fissure veins. The maximum width from wall to wall is about 20 feet, the minimum a mere fracture or series of fractures with practically no width. The wide places occur (1). from the splitting of the vein; and (2) from the movement of the two walls past one another, so that two concave surfaces are brought into juxtaposition. Such wide places run down to mere fissures at both ends, where convex surfaces are in contact; narrow, barren faces may be observed in the southwest end of the Ute workings and in the northeast end of the Hidden Treasure workings.

Through the Ute mine the vein is well defined between two simple walls, but in the Hidden Treasure mine it splits into a number of stringers. At the most important of such splits occurred one of the widest and most valuable bodies of ore. This split is most noticeable on the fifth level, 45 feet northeast of the shaft. One branch of the vein is 10 feet in width, and the other is 4 feet in width. The main vein for 40 feet southwest of the split is 20 feet wide. The junction between these two branches pitches northeast in the plane of the vein, so that on the fourth level it is close to the shaft.

Another irregularity occurs at the southwest end of the Ute workings on the fifth level, where the vein is split into a number of parallel stringers of small size. In a short crosscut northwest from the adit tunnel these stringers are very clearly shown separated from the main vein by spaces of barren but silicified rock; where cut they are 40 feet southeast of the main vein, which here narrows to a maximum width of 2½ feet.

PARAGENESIS.

A number of well-defined steps in the formation of the Ute-Hidden Treasure ore bodies are evident. The first seems to have been the rupture of the country rock with a little but not marked brecciation and but little or no separation of the walls from one another. This was followed by the entrance of silicious mineralizing waters, intensely altering the country rock into hard, greenish silicified material for a short distance from each individual fissure. Later movement separated the walls and moved them slightly past one another, producing the pinches and swells and causing some brecciation of the wall rock.

The first period of vein filling then occurred depositing (1) quartz; (2) rhodochrosite, tetrahedrite, and galena; and (3) quartz. Later movement shattered this vein material and deposited (1) quartz; (2) barite with subordinate galena; and (3) quartz.

ORES.

Character.—The ore in the Ulay vein can not now be described exactly, but it was composed, as nearly as can be learned, of argentiferous galena, with some tetrahedrite, sphalerite, and pyrite, and the usual enrichments of ruby silver. From the upper levels considerable native silver is reported to have been taken. In the lowest or eleventh level the sphalerite increased in quantity and the silver and lead values fell off to such a degree that the mine was abandoned and has not been worked for many years. Some idea of the prevailing character of the ore may be learned from the production statistics for the years 1887 and 1888.

Production of the Ulay vein for 1887–88.

	Gold.	Silver.	Lead.
1887	$1,645	$39,498	$19,242
1888	2,500	84,038	52,800

The absence of copper and the large value of the lead indicate that the product was chiefly argentiferous galena and that there was less tetrahedrite in the ore than in most of the mines of this region.

The ore in the Ute vein was a mixture of galena, pyrite, and subordinate tetrahedrite in a gangue composed mostly of quartz, with subordinate barite and a very small quantity of manganese-bearing minerals. In the pillars left in the mine banded ore containing chiefly galena and sphalerite was observed. In the breasts of No. 5 level about 180 feet southeast of the Hidden Treasure shaft the vein is 4 feet wide and consists mainly of quartz and barite. Many fragments of country rock, generally altered to a very light greenish color, may be seen in the vein.

The sphalerite, galena, and barite of the Ute vein appear to belong to the earlier period of mineralization; in all cases where they could be clearly observed they are older than the gangue of white quartz in which they are embedded. This can be seen from the manner in which a great part of the galena is fractured and broken, and the interstices filled with white quartz, much of it with well-developed comb structure perpendicular to the galena fragments. (See fig. 13.)

Value.—Small bunches and bonanzas of ruby silver in the upper stopes of the Hidden Treasure carried high values in silver, but the general average of the ore extracted from the mine was from $7 to $9 per ton. Milling operations during 1898 and 1899 showed that 1 ton of concentrates, worth $41.67, was obtained from 4.61 tons of crude ore. The cost of operation at the Hidden Treasure, including freight and smelter charges, was about $4.12.

FIGURE 13.—Galena shattered and infiltrated with quartz, Ute vein. *a*, Quartz; *b*, sphalerite; *c*, galena.

Distribution of values.—The distribution of the various minerals in the Ute-Hidden Treasure vein is not uniform. From the southwestern extremity of the Ute vein to a point well within the lines of the Hidden Treasure property, where the crescent-shaped bend in the vein causes it to trend more nearly north, the ore consisted of a banded aggregate of argentiferous galena, sphalerite, quartz, and barite. Throughout this entire distance tetrahedrite is present in small quantities, as is also barite, but rhodochrosite is practically absent. If the workings on the vein had been carried no farther than the Hidden Treasure line, it would have seemed a remarkably clear type of a quartz vein carrying argentiferous galena and sphalerite. Beyond the Hidden Treasure line, however, the barite increases notably in amount and tetrahedrite and rhodochrosite begin to appear in the ore; and finally nearly the whole vein consists of rhodochrosite, with large quantities of tetrahedrite and barite and small quantities of galena. Quartz is present in subordinate amounts. Throughout the long Ute portion of the vein, 3,000 feet in all, the gangue and ore minerals are mingled together with remarkable uniformity, so that for nearly the whole of this length the vein is stoped. No definite pay shoot can be detected, though low-grade areas of small dimensions were encountered here and there and the ore in them was left standing in the mine. In the Hidden Treasure portion of the vein the upper edge of the profitable ore pitches about 15° N., but this pitch is due more to a decrease in the size of the fissure than to the failure of metalliferous mineral contents. The presence also of the branch vein described on page 91 seems to have determined the upper edge of this profitable area. Much difference of opinion among those who operated these properties exists as to the pitch of the shoots, but this arises from the very large area of profitable ore and the consequent difficulty in determining any well-defined shoots. If rhodochrosite and tetrahedrite be regarded as localized from the other minerals in the mine, they are clearly restricted to the north end, but so far as silver values are concerned there seems to be no regularity about the localization.

The ore in the Ulay vein occurred in distinct shoots, two of which were found south and one north of the shaft.

EQUIPMENT.

HIDDEN TREASURE MINE.

The Hidden Treasure mill is connected with the shaft by a Bleichert tramway 3,800 feet in length, with a capacity of 100 tons in 24 hours. Power is obtained by a 150-horsepower Pelton wheel supplied with water from a dam under a head of 118 feet by a wooden pipe line 28 inches in diameter and 1,000 feet in length. The ore goes first through a 9 by 15 inch crusher and thence to rolls, one set 16 by 24 inches, the other 12 by 20 inches, for finer crushing. From here it is sent to a set of trommels, where it is sized, the oversize from the first three trommels being returned to the rolls. The two sizes from the last two trommels pass to two sets of jigs. The fines are sent to two hydraulic sizers and thence to four Wilfley tables, which yield a fair saving. A little of the rhodochrosite is saved from the tables, as it contains high values in silver from finely-divided tetrahedrite. The concentrates are not dried. The concentration is 4.6 to 1. Compressed air is supplied to the mine by a 13½-inch Leyner duplex compressor of 16-inch stroke, which is operated by another 150-horsepower 54-inch Pelton wheel. The hoist is operated by electricity furnished by a 45-kilowatt dynamo, operated by steam.

UTE AND ULAY MINE.

The ore from the Ute and Ulay mine was taken to the mill in Henson Creek by a wire-rope tram. The mill has a capacity of 90 to 100 tons a day. The ore goes first to a rock breaker (Blake, 9 by

15 inches), and then to three sets of rolls (Allis-Chalmers, 16 by 30 inches), then through four successive trommels, 36 inches in diameter and 7 feet long, which size the crushed ore to 8, 6, 4, and 2½ millimeters. The coarse which passes through the trommels goes to the jigs, a double-compartment jig for each trommel. The fines which escape from the last trommel pass into two hydraulic sizers, the coarse being sent to jigs and the fines going into a third sizer. The coarse from this last sizer goes to a jig and the fines run to the buddles, two of which are plain, 16 feet in diameter, and four double-deck, 24 feet in diameter. The tailings pass into settling tanks where the slime is arrested. (See fig. 14.) The Ute ore became much higher in sphalerite on the fifth level, so that the mine no longer paid expenses of operation. In this respect it resembles most of the other veins of the region.

The following statement by Rickard[1] will indicate the manner in which the concentrates are handled:

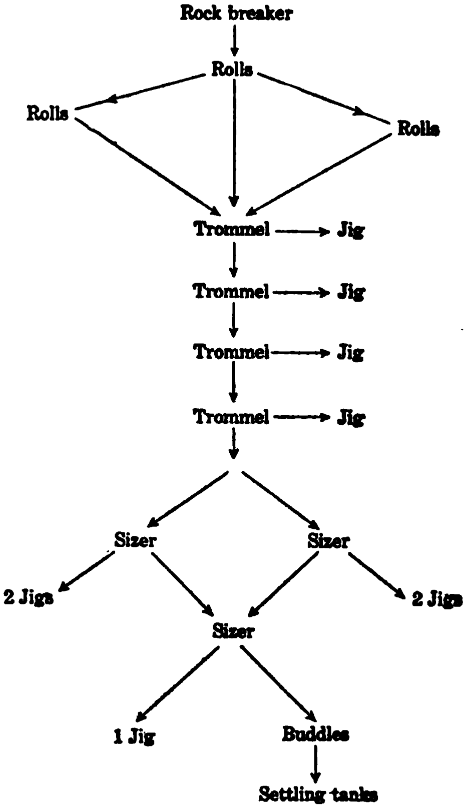


FIGURE 14.—Diagram of treatment at the Ute and Ulay mill. After Rickard.

> The concentrates are dried and mixed by passing through a heated revolving cylinder. About 1½ per cent of moisture is left in the concentrates in order to lessen the leakage arising from the bad flooring of the railroad cars, which would be a greater source of loss if the concentrates were dry enough to run readily. The concentrates contain 58 to 61 per cent lead, 13 to 15 ounces of silver, and 0.05 to 0.06 ounce of gold per ton. They represent about 16 per cent in weight of the original ore and an extraction of about 80 per cent of the lead and 65 per cent of the silver.

PELICAN.

The Pelican mine is situated in a small dry gulch on the north side of Henson Creek about 1½ miles due west of Lake City, at an elevation of 9,630 feet above sea level and 875 feet above the bottom of Henson Creek. The mine is connected with the main wagon road in Henson

[1] Rickard, T. A., Across the San Juan Mountains: Eng. and Min. Jour., vol. 76, 1903, pp. 461-462.

Creek by a rough second-class road about half a mile long, down the north side of the canyon. Power has been furnished by a gasoline engine.

Production and development.—The first mention of the Pelican in the mint reports occurred in 1891, during which year it is credited with a production of $581 in silver. The following year it produced $1,503, all silver except $20 in gold.

It is reported that two shipments of about 10 tons each showed returns of 0.69 and 0.63 ounce of gold and 165 and 129 ounces of silver per ton. To one of these shipments 2.07 per cent of lead is credited.

The workings of this property consist of two shafts, two levels, a winze, and several small stopes. The shafts are respectively 75 and 38 feet deep, the first one connecting the first level with the surface. The winze is only 35 feet down from the first level. The first level is approximately 450 feet long, and the second (200 feet below the first), is about 900 feet long. All the workings except a 400-foot crosscut on the second level are on one or another of the veins which form the fracture system making up this deposit. The amount of stoping is comparatively small. One block, approximately 28 by 38 by 4 feet, had (1908) been worked at the shaft on the upper level. Another block, approximately 56 by 50 by 2½ feet, had (at the same date) been extracted near the breast of the first level.

Country rock.—The vein is in Eureka rhyolite, the latter having been slightly altered along its contact with the mineralizing agencies. Marked disturbances were noted in the country rock between the crosscut and the vein worked in the second level.

Veins.—In the stope above the lower level the most prominent vein is 3 to 4 inches wide, with an ore course varying from one-eighth to one-fourth inch in width and is frozen to the walls. It strikes N. 10° E. and dips 66° S. 80° E.; the other veins differ somewhat, both in dip and in strike.

The ore body is a typical filled fissure. It varies in width from about 2 inches to 4 feet at the widest points, with an average of 1 foot. The dip is fairly uniform, being 70° SE. The vein is formed along two series of intersecting fractures, which strike N. 10° E. and N. 35° W. No one of these fractures is very long and the main open space extends along one fracture until this becomes narrow, and then passes to a fracture of the other strike, to be again taken up by a fracture parallel to its first course, and so on. This feature is well shown in figure 5 (p. 42). It is probable that similar variations could be observed in dip, but exploration is not yet sufficient to disclose them. The fissuring has been accompanied by very extensive brecciation, so that the vein is characterized by many angular inclusions of country rock, by innumerable branches, and by other irregularities. (See fig. 15.) In places it is merely a sheeted zone which has but little open space for ore deposition.

The structure of the vein filling appears massive on first sight, probably on account of the great mass of highly altered rock with which the fissure is filled, but on closer examination very fine druses are often discernible, either parallel to the walls or following around the periphery of included fragments.

Replacement of the country rock has been more extensive in this vein than in most of those in the region. Here, as elsewhere, however, it has been chiefly confined to silicification, which has transformed the included rock fragments into hard black flinty silica. Barite has also been to some extent introduced into the wall rock, and included fragments show a higher degree of replacing action than common.

The accompanying sketch shows the brecciated nature of the vein.

Ores.—The vein filling consists of the following minerals, named in the order of deposition: Primary minerals, black dense silica, barite, galena, freibergite, barite, white quartz, pyrite, and sphalerite; secondary minerals, pyrargyrite and secondary galena. Silica and barite are the most abundant.

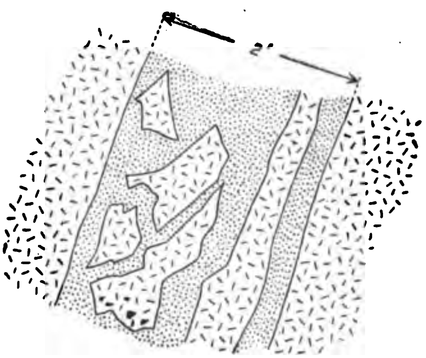


FIGURE 15.—Face of Pelican drift, showing structure of lode.

A little rhodochrosite also occurs in subordinate amount. A number of these minerals, especially barite and quartz, probably appear in more than one generation, but the relative periods of deposition can not in all cases be made out with certainty.

The secondary pyrargyrite and secondary galena are without doubt connected genetically with oxidation processes. The pyrargyrite occurs in later crevices in the ore as well as in defined crystals lying on the outer surface of the white quartz druses in open cavities. It has, with little question, originated from the reprecipitation of antimonial silver solutions derived from the alteration of the freibergite (p. 63). It is probable, for this reason, that the ruby silver will not continue in depth, or at least will occur only as far as surface solutions could gain access along especially favorable channels.

The ores contain many irregular vugs, some of them 8 inches or more in diameter. Nearly all of them are lined with white quartz, usually in fine druses. Barite crystals project into many of them, but all of these are covered with a fine coating of white quartz, showing that silica was the final phase of the deposition. What is probably secondary galena occurs coating the surface of the sphalerite along cracks and fractures in the ore. In the hand specimen it may be seen merely as a dull lusterless surface, slightly grayish in appearance, in sharp contrast to the brilliant luster of the fresh fracture of the sphalerite when this mineral is broken, where no crack large enough to permit the entry of surface solutions has been available; under the microscope, however, it is distinctly coated with some gray mineral. In some massive sphalerite the minute galena-coated crevices are so numerous that it is nearly impossible to break the ore so as to get a perfectly fresh fracture.

MISSOURI FAVORITE.

The Missouri Favorite mine is on an unpatented claim located just north of Henson Creek, about three-quarters of a mile west of Lake City. The mine is one of the most accessible in the region, being near the railroad terminus and a source of supplies.

Production and development.—Little is known regarding the history of the mine. Mr. Snyder of Lake City has worked the property for a number of years and has made two shipments of ore, one of 10 and another of 8 tons. The first shipment gave returns of $8 per ton and included 800 pounds of sacked ore, which ran $247 per ton. The second shipment ran $50 per ton. These are picked lots of ore and do not represent the average run of the ore body.

The development on the property consists mainly of drifts. One drift runs about 600 feet from the mouth of the adit tunnel along the main vein. Some 250 feet in a stringer, making an angle with the main drift of 20° to 30° to the northwest, has been followed for 350 feet.

Veins.—The vein is in Eureka rhyolite, which shows more alteration than is common in the area. In general the localities showing the greatest amount of alteration and decomposition appear to have been the least prospected, and, indeed, have been left practically unexplored on any extensive scale. The cause for this is not apparent, although it may be due to the fact that nearly all of the mining operations in the Lake City district have been either in connection with placers or on well-defined quartz veins, and the prospector is loath to take up a new kind of exploration.

The faulting in the vicinity of this vein is more noticeable than it is near many of the mines visited. Most of it seems to have occurred on the west side of the vein, where great slickensided surfaces are common. Gouge is present in enormous amounts and during wet seasons of the year clay and mud fall from the roof in tons. The hanging wall is in several places separated from the footwall by a great wide fissure filled with clay and mud. As the portion of the vein developed is near the grass roots, much of the clay and mud may be due to surficial wash. Toward the west of the main working an enormous horse comes in and separates the two walls by 30 or 40 feet.

From the foregoing it may be inferred that the fissure is irregular and shows great variations in size and character. The strike of the vein is about N. 50° W., although there are so many variations that only an approximate direction can be given. The dip is in general about 70° SW. The width varies from a few inches to several feet.

Ores.—The ore minerals are galena and tetrahedrite with some chalcopyrite and sphalerite. The gangue is composed almost entirely of barite with a little quartz. The ores show banding, as is common in the ores from this area. The alternate layers of decomposed rock, barite, and ore minerals resemble parts of the Ute-Hidden Treasure vein.

SAN CRISTOBAL GROUP.

MONTE QUEEN.

The workings of the Monte Queen mine lie due south of Lake City, on the west side of Lake Fork, on the eastern slope of the mountain, 9,100 feet above sea level and 300 feet above the bed of the river. The mine is connected with the main road by a short branch road which makes it easily accessible.

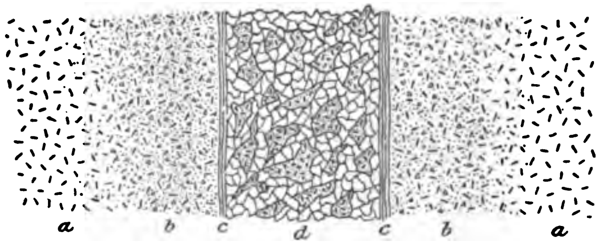


FIGURE 16.—Cross section of the Monte Queen vein, showing included rock fragments, strong selvage, and massive vein filling. *a*, Unaltered country rock; *b*, silicified flow breccia; *c*, selvage; *d*, fragments of country rock and barren quartz gangue.

Vein.—The vein is opened on its outcrop by a tunnel driven S. 73° W. for 950 feet. The country rock is a grayish stratified breccia evidently formed by the fracture of the cooling upper surfaces of successive lava flows during their extrusion. Some stoping has been done in the mine, but no records of its production or history could be obtained.

The workings are on a fissure vein, produced in greater part by the filling of an open crevice and only in minor degree by replacement of the country rock. The vein, which departs but little from the vertical in its explored portions, is about 3 feet in width. In some places it has well-defined walls, locally separated from the country rock by strong selvage seams. (See fig. 16.)

Ores.—The ore minerals are segregated within the barren gangue material into vertical shoots which show no appreciable pitch within the plane of the vein (see fig. 17). Between the shoots the vein

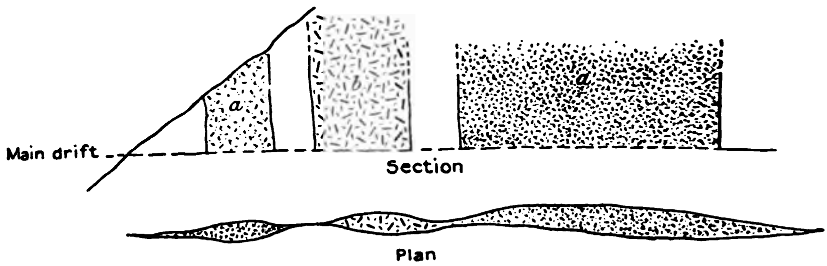


FIGURE 17.—Plan and longitudinal section of Monte Queen vein, showing ore shoots. *a*, Tetrahedrite and pyrite; *b*, galena and zinc.

pinches so that only a few sheeting planes with stringers of quartz, etc., are left, by which the vein may be followed from one shoot to the next. The shoots have a stope length of 50, 63, and 200 feet, respectively. Nos. 1 and 3 contain chiefly pyrite and some gray copper ore and do not run very well in silver. No. 2 consists chiefly of a peculiar dark-brown, fine-grained, massive, rosin-like sphalerite, mixed with fine steel galena and averaging about 75 ounces in silver and notable percentages of bismuth. Some of this ore, according to the management, ran as high as 2,000 ounces in silver and contained 20 per cent of bismuth. The pyritic shoots were too low grade to pay. A fourth shoot, or widening of the vein, 5 feet in width, occurs in the breast of the tunnel 950 feet west of the mouth; so far as yet explored it contains nothing but massive rhodochrosite.

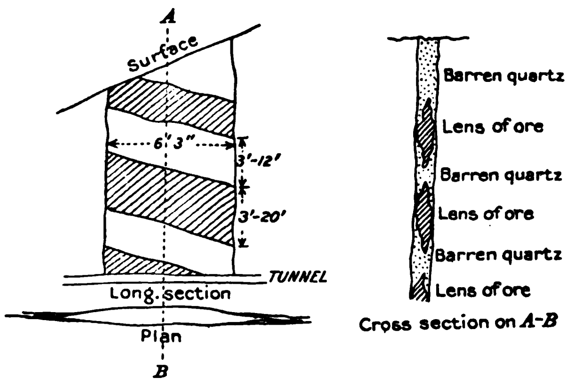


FIGURE 18.—Occurrence of shoots within shoots, Monte Queen vein.

The metallic minerals in the No. 2 shoot occur in smaller shoots, which are separated by vertical intervals of barren quartz and are lenticular in both vertical and horizontal section; they pitch slightly (15°) along the course of the vein to the southeast. The vertical extent of these lenses is from 3 to 20 feet (see fig. 18) and that of the barren quartz filling between from 3 to 12 feet. The barren portions are filled with included and highly silicified fragments of wall rock and the country rock is altered to distances of 4 to 5 feet from the vein filling.

NELLIE M.

The workings of the Nellie M. mine are west of those of the Monte Queen. The vein is opened by an upper and a lower drift. The upper tunnel, which is 510 feet in length, runs S. 53° W. with the vein. The lower tunnel is 700 feet in length. The country rock is the usual bedded type of andesitic and rhyolitic flow breccia, much decomposed, and with very prominent banding. The dip is 65° S. The vein, so far as could be learned, has not yielded ore in commercial quantities, but a little sphalerite, chalcopyrite, and some silver have been found. A few streaks of metallic mineral could be seen here and there along the broken sheeted zone followed by the tunnel.

LODE STAR

The Lode Star mine workings consist of a shallow shaft and a few short tunnels located on a shear zone from 2 to 300 feet wide. This zone has had so little work done on it that its nature can not be determined. The mineralized zone is greatly stained with iron oxide, is much silicified, and is reported to have yielded some values on assay, but has so far not paid for what exploration has been done.

DAUPHIN, ROB ROY, AND SULPHURET.

On the east side of Lake Fork, about 1¼ miles south and a little east of Lake City, is a great shear zone striking about N. 73° E. On one side of this are the workings of the Rob Roy and Dauphin and on the other to the southeast are those of the Sulphuret. Sufficient work has been done to disclose some gray copper ore, several carloads of which have been shipped from the Sulphuret; but the development is insufficient to furnish any reliable data. It is possible that the Sulphuret may represent the northeast continuation of the Monte Queen vein.

GOLDEN WONDER.

The geologic map (Pl. III) shows an area of silicified rhyolite covering a large part of the southeastern portion of the Lake City quadrangle. Within this area, some 2½ miles southeast of Lake City, is the Golden Wonder mine. This property is unique in that it is the only deposit of those examined by the writers in this area that can be classed as a true replacement deposit.

The Golden Wonder claim is on the northern side of Deadman Gulch, its side lines extending east and west, approximately parallel to the trend of the gulch. A good trail connects the workings with the main wagon road to Lake City. Underground examination of the Golden Wonder was not possible because of the condition of the workings, but a basis for conclusions as to its deposits was supplied by the examination of contiguous and doubtless analogous deposits.

Few authentic data are available in regard to production. Two carloads of ore are reported to have been shipped in 1906 which are said to have averaged $70 a ton in gold.

The original discovery was made at an elevation of 10,500 feet, at which height an adit tunnel is said to have been driven 150 feet east into the silicified country rock. Another adit tunnel, started at an elevation of 10,375 feet, near the center of the gulch, is said to have been driven 850 feet. This crosscut is not a direct one, but is reported to twist and turn in a remarkable manner.

The country rock in this vicinity is an altered rhyolite, doubtless of intrusive origin. This rock has been greatly changed by silicification and in places by sericitization. Solutions containing pyrite have impregnated the surrounding rocks for several miles in all directions, and it is probable that in these is to be found the source of the gold found in the Golden Wonder workings and elsewhere in the vicinity, local concentrations of the gold contained in the pyrite having produced the few rich pockets found in the vicinity.

True quartz veins are scarce in the workings examined on contiguous properties, the mineralization appearing to be a simple replacement of the country rock by silica and pyrite. In places, however, mineralization, presumably by secondary concentration, has taken place along joint planes and fracture zones in the altered rhyolite.

MAYFLOWER AND CONTENTION CLAIMS.

The Contention mine includes the Contention and Mayflower claims, which are located about 1,000 feet north of the north end of Lake San Cristobal and 3 miles south of Lake City. The claims are so located that the west end of the Mayflower adjoins the east end of the Contention.

Production and development.—For short periods during its history the mine has produced a considerable amount of silver from its upper workings. The ore bodies were small, however, and the mine has not at any time been capable of maintaining a heavy output. For the four years, 1889 to 1892, the following statistics on the Mayflower and Contention are given:

Production of Mayflower and Contention claims, 1889–1892.

	Gold.	Silver.
1889	$120	$905
1890	63	1,244
1891		2,456
1892	47	3,543
Total	230	8,148
Grand total	$8,378	

VIEW LOOKING SOUTH UP LAKE FORK.

Lake San Cristobal shows in the distance. Contention Mill is on the right. Photograph by Whitman Cross.

The workings are located on the west side of Lake Fork just above the wagon road from Lake City. The tunnel openings by which the vein is reached lie on the extreme north end of the Mayflower claim, but most of the work is on the Contention claim. (See sketch, fig. 19.)

The mine is opened by three tunnels, two on the Mayflower claim and one on the Contention. The lower tunnels follow the vein westward into the hill and show low-grade ore. The upper tunnel and the workings connected with it are now abandoned but show considerable stoping and indicate that quite a little ore has been removed.

A large mill for treating the ore was erected in 1904. From the Gates crushers the ore was sent to rolls, thence to screens and to a Huntington mill, thence to classifiers, and after that to Wilfley tables. A high-grade concentrate was obtained, and the management claims to have saved 90 per cent of the gold and 88 per cent of the silver.

Country rock.—The country rock is the Picayune volcanic group. The ore body is a fissure vein with a nearly vertical dip, with a slight northward tendency, and a somewhat variable trend, averaging approximately S. 60° W. to S. 79° W.

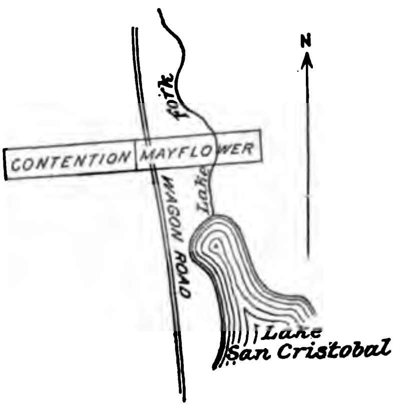


FIGURE 19.—Sketch of Mayflower and Contention claims.

Vein.—The vein, which has an average width of from 14 inches to 2 feet, is in places single but not uncommonly splits into stringers along the strike. In the lower tunnels it is more irregular than in the upper tunnels and stopes, from which practically all of the merchantable ore had been taken at the time of examination in 1904. Pinches and swells are numerous, the vein having practically no width between stopes. Banding is generally imperfect or absent except in small quartz offshoots, where comb structure is better developed.

Ores.—The ore consists of silver-bearing gray copper or freibergite, (slightly auriferous), sphalerite, chalcopyrite, and pyrite in a gangue of quartz, barite, and rhodochrosite.

In the upper workings the gray copper predominates and often makes up the bulk of the ore with a little rhodochrosite, but in the lower tunnels pyrite is in greatest abundance and gray copper of only secondary importance. Some of the upper ore was extremely rich, $60,000 worth of silver having been extracted from a single small pocket. Barite and quartz are less abundant in this upper ore.

The ore from the lower tunnels is a massive aggregate of dense, fine-grained chalcedonic silica containing innumerable large, open vugs. In this quartz great numbers of thin tabular crystals of barite form a network which in many places resembles the feldspars in a coarse diabase. Mixed through this quartz-barite gangue is fine-grained noncrystalline pyrite, sphalerite, and tetrahedrite, with very subordinate galena and chalcopyrite. Open vugs are lined with beautiful crystals of barite generally coated with druses of quartz. Except that the quartz which coats the barite crystals is the last formed, the relative ages of these different minerals can not be definitely determined. In much of the ore secondary pulverulent chalcocite has been deposited as a secondary sulphide on the surface and in the cracks of the pyrite crystals. The wall rock has been very much altered by the vein solutions and shows a white bleached appearance for more than a foot beyond the boundary of the vein matter. This bleached rock has been extensively sericitized and is heavily impregnated with cubical pyrite. The gray copper and other metallic minerals do not extend beyond the zone of the main vein mass.

The ore occurs in shoots, between which the vein pinches to a narrow sheeted zone, which is slightly replaced by silica and a little pyrite, but has afforded no open space for deposition. The upper and lower workings were not connected at the time of the investigation, and the manager was of the opinion that they are not on the same vein, owing to the greater preponderance of the gray copper in the upper workings; in the writers' opinion, however, this difference is due simply to the customary gradual falling off in high-grade silver minerals with increasing depth.

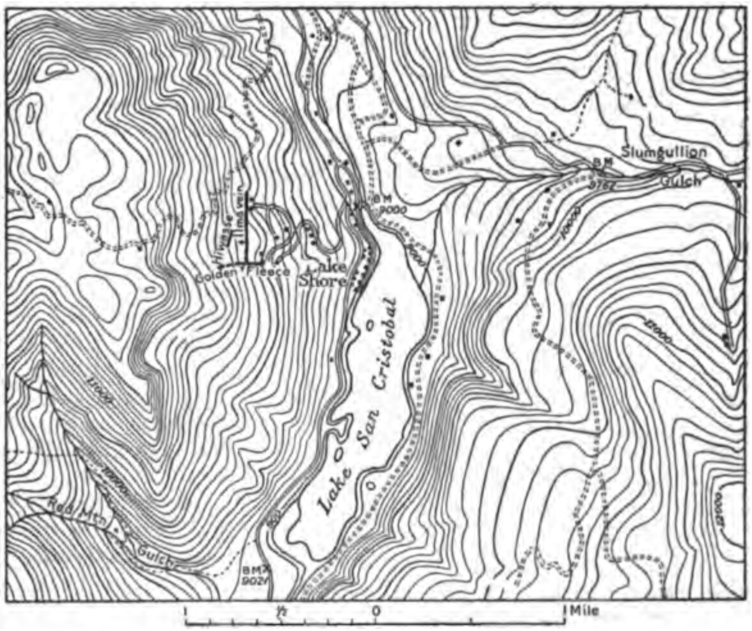
The gray copper is the most valuable mineral normally found in the ore body; in the upper or more oxidized portions of the old workings, however, extremely valuable pockets of ore carrying native silver are reported to have been found. The gray copper carries high values in silver, and where massive often assays as high as 1,000 ounces to the ton. The pyrite in the lower ore carries gold, and a test sample of 2,500 pounds is reported to have yielded 0.28 ounce of gold and 11.34 ounces of silver.

GOLDEN FLEECE.

The Golden Fleece mine contains one of the celebrated veins of Colorado, and it is much to be regretted that the condition of the workings has made an exact and satisfactory examination of the mine impossible. A large portion of the upper workings is now inaccessible, no faces of ore remain in what few stopes can be observed, and the nature of the ore from the most productive portion of the mine can be determined only from specimens preserved in the offices of the company or casually picked up on the old dumps of the mine. The description of the mine here given, therefore, leaves much to be desired, though it is hoped that it may prove serviceable to those who are interested in the property.

Location and history.—The upper and productive workings of the mine (see Pl. VII) are located about 2,600 feet west of the north end of Lake San Cristobal, on the easterly slope of a flat-topped, mountain 11,800 feet high. The workings are about 10,000 feet above sea level and 1,000 feet above the level of the lake. (See fig. 20.)

The outcrop of the vein is located in a broad gulch that runs with the slope of the hill. It trends about N. 60° E., forming a promi-



Contour interval 100 feet.

FIGURE 20.—Topographic map of the region around Lake San Cristobal.

nent ridge that rises sharply from the broad bottom of the draw to a height of 100 to 150 feet with a width of 20 to 30 feet. (See fig. 21.)

The mine is reached by a good wagon road from the lake, and transportation of ore to Lake City has offered no serious difficulties.

The history of the Golden Fleece and Black Crook mines is interesting, and the following extract has been taken direct from an article by Rickard:[1]

In 1874 Enos F. Hotchkiss, connected with a Government surveying party which was laying out a toll road from Saguache to Lake City, caught sight of the outcrop of the Golden Fleece standing conspicuously above the hill-slope, and examined it. He located it as the "Hotchkiss" mine and had some assessment work done while

[1] Rickard, T. A., Across the San Juan Mountains, Eng. & Min. Jour., vol. 76, 1903, pp. 307-308.

he was engaged in his survey work in the vicinity. As far as known he found no ore. A year later, when Hotchkiss had abandoned his claim, it was re-located by George Wilson and Chris Johnson, under the name of "The Golden Fleece." They began what is now known as the No. 1 tunnel, but finding only little stringers of rich ore, they ceased work. Others did similar desultory prospecting. O. P. Posey found a very rich bunch of ore in the croppings above the No. 1 tunnel and took out several hundred pounds, which were packed to Del Norte and sent thence to the Pueblo smelter. Then John J. Crooke took a lease and bond; he also extracted about $30,000 from the outcrop above No. 1 tunnel, which had been extended a little farther, without result. This was between 1876 and 1878. In 1889 Charles Davis took a lease and bond; he did a good deal of work along the high croppings and finally sunk a shaft 30 feet deep, which struck a body of ore yielding $40,000 in a very short time. Later in that year, 1889, George W. Pierce bought the mine for $50,000 and commenced extensive explorations. He found out very soon indeed that Davis had extracted all the ore in sight, and the outlook was not cheerful. All the work up to this time had been to the north on the supposition that the vein had been faulted in that direction. The new owners crosscut south at the No. 2 tunnel, which had been previously extended a little way, but had found nothing. The vein was picked up, but not much ore was encountered at first. They persisted, however, and within a year rich ore was cut on No. 2, and it was traced upward until it became easy to intercept the same body at No. 1. It was discovered that the former owners had been within 10 feet of the main ore body of the mine, which from that time until 1897 was very profitable.

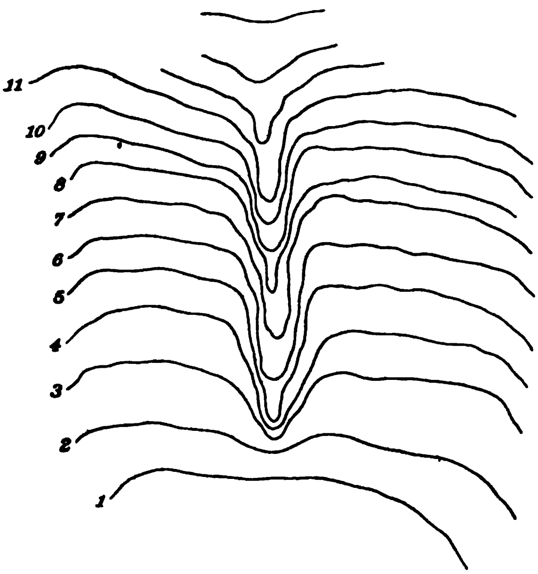
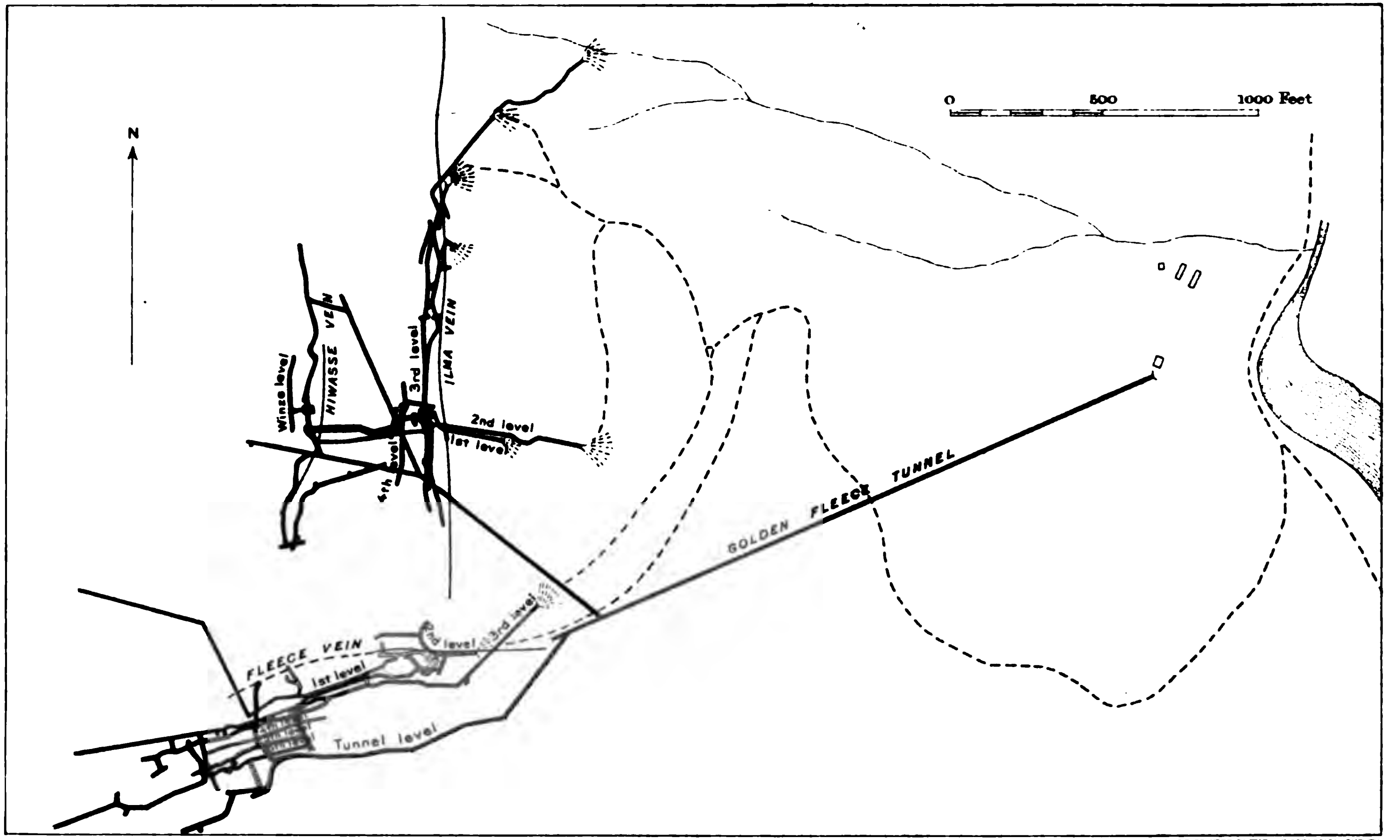


FIGURE 21.—Sketch of ridge formed by the outcrop of the Golden Fleece vein. (Not to scale.)

Nearly all of the ore of merchantable grade produced was taken from the stopes above the third level. A few bunches of high-grade ore were found down as far as the main tunnel, where one bunch gave the phenomenal assay of 125 ounces gold and 1,255 ounces of silver. This was very exceptional, and no ore has been found in quantity below tunnel No. 3.

The rich ores of this mine did much to stimulate active prospecting in this region, and it is probable that to it are indirectly due many of the other discoveries in the district.

Development and production.—The vein is opened by four tunnels. Two of these are drifts on the vein and are located on the crest of the



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PLAN OF THE WORKINGS OF THE GOLDEN FLEECE AND BLACK CROOK MINES
1911

ridge made by the outcrop. Below is a short crosscut tapping the vein at a slight angle. In and above these three upper levels are located the large stopes from which nearly all of the rich ore of the mine was taken at a maximum depth of not more than 400 feet from the surface. A shaft connects with the upper level west of the mouth. From the lowest of these three levels the vein was for some time worked through winzes, but later a long crosscut tunnel was driven 1,200 feet below the collar of the shaft. This intersected the vein and intermediate levels have been worked by means of it. (See fig. 22 and Pl. VII.)

According to Mr. George W. Pierce the mine produced $1,400,000 up to 1904.

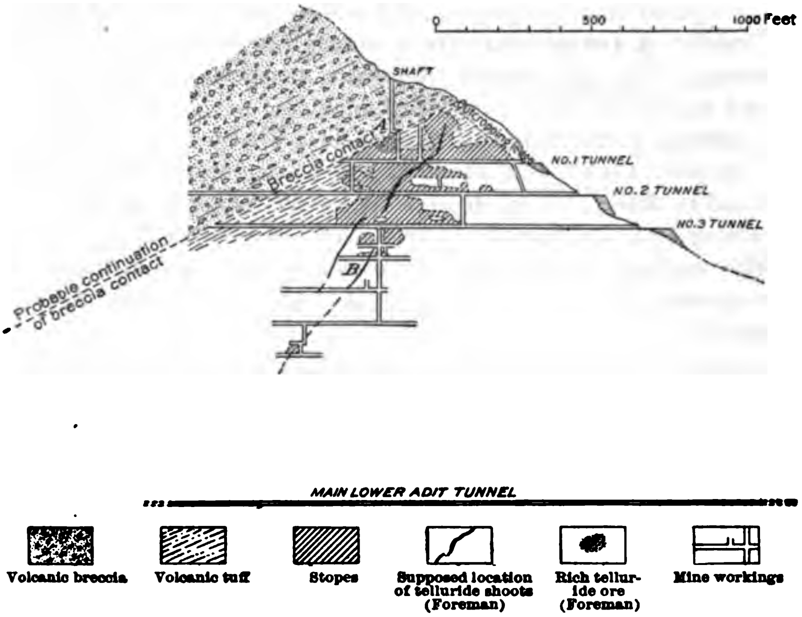


FIGURE 22.—Longitudinal section of the Golden Fleece vein, showing position of agglomerate contact and ore shoots.

Country rock and structure.—The country rock of the Golden Fleece consists of a series of plainly stratified flow breccias interbedded with volcanic tuffs and agglomerates. The planes of stratification are peculiarly well seen in the weathered rock, which is whitish and decomposed into a loose friable clayey material. In the Ilma workings, north of the Golden Fleece mine, these tuffs and breccias dip east, but in the Golden Fleece they are reversed to a strong westerly dip of 27°, which prevails through both surface workings and in depth.

Above the highest tunnel the fine-bedded tuffs and flow breccias give place to a conformable series of extremely coarse agglomerates containing subangular bowlders embedded in a yellowish tuffaceous matrix. Many of these bowlders are several feet in diameter and constitute most of the rock, the matrix being greatly subordinate. They are composed of the same material as the finer tuffs and breccias below and in many places show well-marked banding, set at all angles according to the position of the bowlder at the time of deposition. This coarse agglomerate, which is very thick, was traced up the hill to beyond the upper tunnel, but its total thickness was not determined.

The contact of this agglomerate with the underlying beds is conformable, but, as explained below, is probably also a bedding fault. The vein throughout all of the upper workings, where explored, terminates against this contact as a roof and nowhere enters the agglomerate itself. A tunnel was driven across the contact into, though not through, this agglomerate, disclosing neither a different type of rock nor any evidence of mineralization.

The abrupt termination of the Golden Fleece vein against this plane has been the cause of much expensive exploration and has been explained in different ways by different observers. Rickard believes that owing to the different physical character of the coarse breccia and the underlying tuff the vein broke into minute stringers and never penetrated the coarse breccia. His description warrants quotation:[1]

> The outcrop ceases when the vein encounters the coarse breccia; so, also, in the underground workings the vein itself comes to an end with a suddenness which is, however, only comparative. The contact has been considered a fault; a good deal has been said concerning its regularity and clean-cut character. This, however, does not, I believe, accord with the facts. The so-called fault is not a break or dislocation in the rocks; it merely marks the division between the layers of fine-grained breccia and an overlying formation of very coarse breccia. There is no smooth plane or wall or defined parting between these two formations, but only a sudden transition, which at a distance is more marked than near by. * * * The contact existed before the vein was formed. The fracture, followed by the ore, passed easily through the finer-grained rock, but ceased abruptly when it met the beds of coarse breccia, because the force of fracturing was not only insufficient to overcome the resistance of the harder fragments contained in the latter, but it must have been dissipated by the encounter with a loose-textured body of rock, much in the way that the power of a diamond drill becomes wasted in passing into a shifting mass of loose conglomerate. As a consequence the energy of shattering was diverted along the contact, the vein fracture ceased, and the later ore-depositing waters were barred from further advance into the coarse breccia, save as a scattering confined to the neighborhood of the contact. At the third level the ore body, occurring in the fine-grained country, was notably wider immediately at the "contact," and in examining the outcrop of the vein I noticed that it was difficult to decide upon the exact line of separation between the two formations, because the mineralization extended from the fine into the coarse breccia so as to obscure the divisional plane.

[1] Op. cit., p. 346.

The writers can not agree with Rickard as to the nature of this plane. They were unable to note any points at which the ore actually entered the coarse breccia, but did, on the contrary, detect fragments of ore material included in the breccia along the line of division between the two series. In their opinion, therefore, the line of demarkation between the coarse breccia and tuff has been also the locus of a bedding fault which has occurred since the vein formation and has disturbed the continuity of the vein. Whether exploration will reveal the westward extension of the Golden Fleece vein in the coarse agglomerate or not can not be said, and it is doubtful if the different character of rock would permit its continuation with any degree of regularity, but the writers believe that the faulted portion exists and may yet be found.

Vein.—As far as could be determined from the exposures seen and the specimens obtained, the vein of the Golden Fleece mine consisted of a mass of very irregular broken country rock with interstices filled with dense granular gray and white quartz and fragments intensely altered to a hard fine-grained silicious rock impregnated with petzite, tetrahedrite, and other minerals. This ore formed an irregular zone 8 or 10 feet in width, which from the superior hardness imparted to it by mineralization stood out in prominent outcrop above the surrounding rock. This outcrop was stained brilliant yellow, with here and there a reddish cast, both probably due to the presence of oxidized iron minerals and to the kaolinization of the clayey material in the tuffs. Some brick-red stains are also believed to be due to the presence of tellurous oxide.

The outcrop is now honeycombed by the work of leasers gouging around for the many small patches of high-grade ore found near the surface. In the upper levels the vein seems to have had no definite walls, but to have simply faded out into less broken and unmineralized rock. In the lowermost levels (main tunnel level) it is a narrow but distinct filled fissure with fairly definite walls. The vein here could be clearly seen only in the face of the long tunnel, and consisted chiefly of light pink rhodochrosite, containing comparatively little metallic mineral.

From a wide broken zone at the surface the vein, as stated, narrows down in depth to a fraction of a foot. Between the main or adit tunnel level and the third level it could not be seen, and therefore its character could not be determined.

The vein in the lower levels shows the character of most of the veins of this region; that is, instead of remaining a single fissure it splits into a number of smaller fissures which separate more widely in depth and branch out from each other when followed along the strike. (See fig. 23.)

Ores.—The ore from the Golden Fleece mine consisted of petzite, yrite, argentiferous tetrahedrite, galena, hinsdalite,[1] and pyrargite in gangue of fine-grained gray and white quartz and some rhodochrosite. s the mineral hinsdalite is new, its association with telluride ores is nteresting. The gray color of the gangue is in places due to the prence of minutely divided grains of petzite.

Of the metallic minerals, petzite is the most important and carried he chief gold values of the mine. Galena was scarce and gray coper fairly abundant. The latter mineral offered something of a conrast to its occurrence in other Lake City veins, as it rarely, if ever, ontained more than $60 worth of silver per ton.

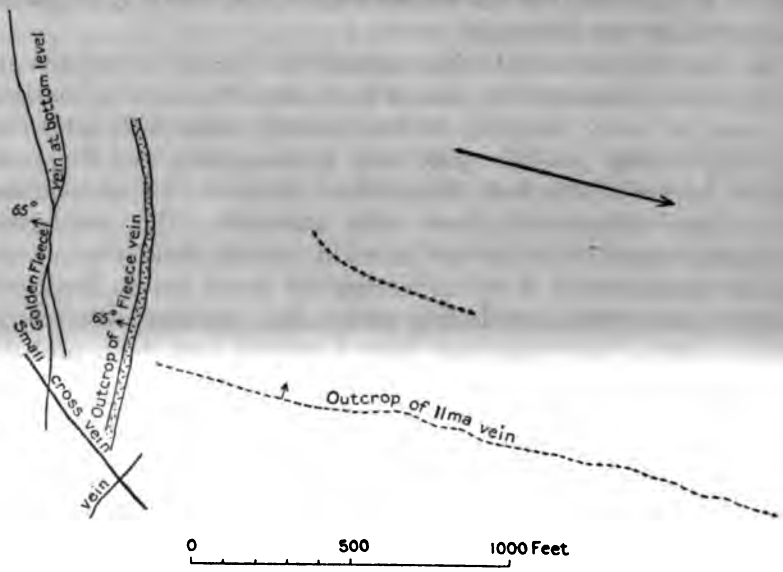


FIGURE 23.—Outcrop and branches of Golden Fleece vein.

The ruby silver came in irregular bunches, some of which are reported to have been found 1,200 feet below the surface; but they were very much more common in the zone of sulphide enrichment and, in the writers' opinion, are clearly of secondary origin. (See pp. 62–63.)

The proportion of gold to silver in the ore may be seen from the following record of carload shipments furnished by the management:

Precious metals in ore of the Golden Fleece mine.

Class of ore.	Gold.	Silver.	Ratio by weight.	Ratio by value.
	Ounces.	*Ounces.*		
1	134.10	3,077.0	1:23	2:1
2	6.11	238.0	1:40	1:1
3	2.0	53.0	1:26	10:7
4	0.40	15.0	1:37	1:1

[1] Hinsdalite is a new mineral described more in detail on p. 54.

Apparently the richer ore had a slightly higher proportion of gold, but in general the ratio of silver and gold by value may be said to have been roughly 1:1.

Most of the rich ore of the Golden Fleece mine was shipped to the smelters, but the low-grade mill stuff was treated on the spot. As the values were chiefly contained in telluride minerals (principally petzite, but also some hessite), the treatment, by concentration, presents features of interest. The mill was of latest design, erected by Stearns, Roger & Co. It consisted of rolls for crushing, Huntington mills for regrinding, Wilfley tables for concentration, and a canvas plant for slimes. No use was made of amalgamation. The Huntingtons were provided with screens of 30 mesh, and experience showed later that 20 mesh would have been better. In treating 18,000 tons having an average assay value of $10.25, half of which was in gold and half in silver, the extraction averaged between 45 and 60 per cent; 63 per cent was the best result. The concentrates contained 55 to 65 ounces of silver, 1 to 3 ounces of gold, and 12 to 18 per cent of lead, in the form of galena. The concentration was in the ratio of 12 to 1.[1]

The ore in the vein (see fig. 23) occurred in a shoot measuring about 750 feet along the levels. As it was followed down, this shoot narrowed to a point below which only isolated bunches of ore were found. Within this shoot a more or less central interior shoot of unusually rich telluride ore is reported to have occurred, as indicated by the wavy black lines in figure 22. An extremely rich bunch of telluride was also found above the first level, west of the shaft, adjacent to the contact of the overlying volcanic agglomerate.

It is notable that this ore shoot occupies nearly the position that would be taken by the trace of the intersection of the Ilma and Golden Fleece veins, but as this intersection could not be actually observed it is not possible to define its effect on the production of the shoot.

The depth of oxidation as affecting the transformation of tellurides into the native metals does not seem to have been great, but as no observations could be made in the upper stopes this must remain uncertain. Secondary enrichment, though apparently without effect on the tellurides, has undoubtedly led to the formation of the rich masses and bonanzas of ruby silver found here and there throughout the mine, presumably by the solution of the tetrahedrite and its later precipitation as the richer mineral pyrargyrite. The fact that bunches of this ore were found 1,200 feet below the surface shows that the surface water has been able to penetrate along cracks and crevices to considerable depth. The ore has without doubt originated chiefly from a replacement of the country rock and a subordinate amount of actual cavity filling.

BLACK CROOK.

The Black Crook mine is on the eastern slope of the mountain which lies 2,400 feet west of the north end of Lake San Cristobal, north of and adjacent to the upper workings of the Golden Fleece.

[1] Rickard, T. A., op. cit., p. 346.

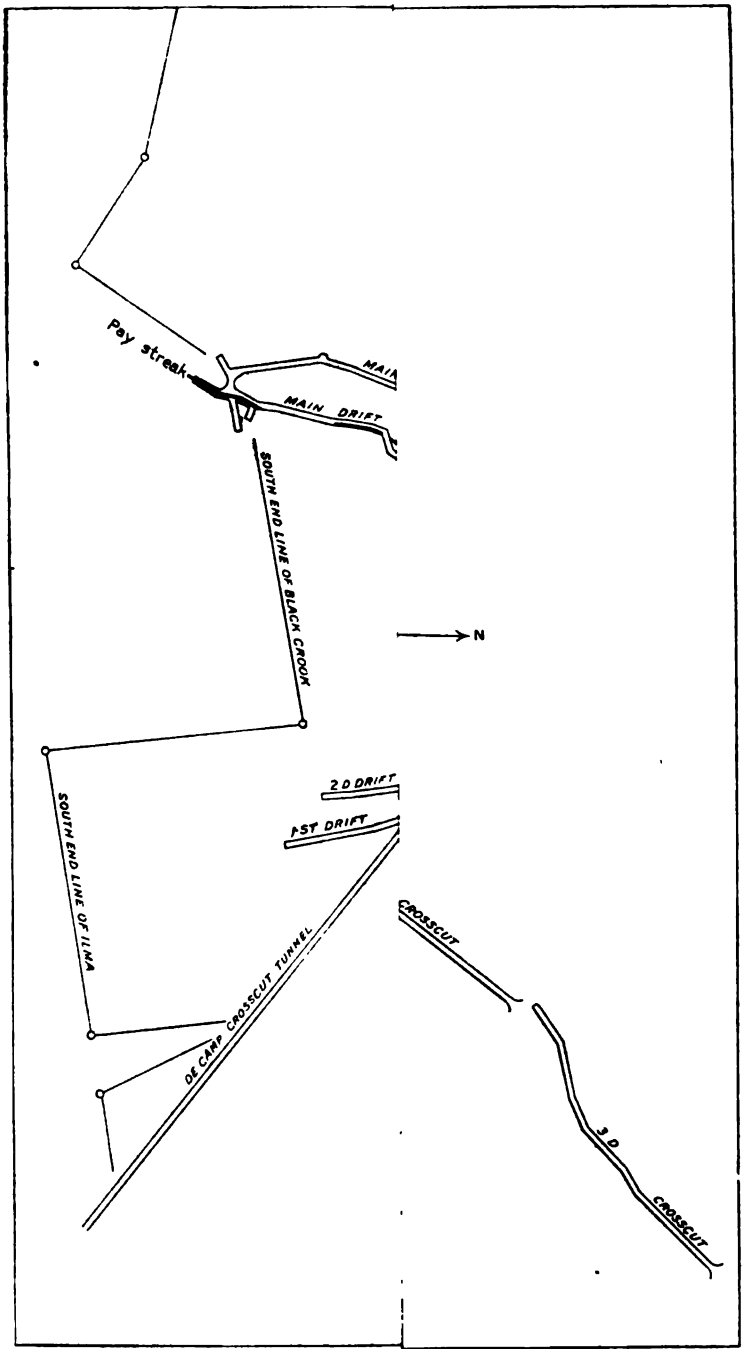
It is approached from the main wagon road in the valley of Lake Fork by a wagon road which winds upward over the hill. The mine was operated intermittently for perhaps 12 years until about 1903.

Development.—The outcrop of the vein runs along the brow of the hill 1,264 feet above Lake San Cristobal, bending westward more than the strike, owing to the westerly dip and the curve of the hill. The mine is opened by crosscut tunnels. Two of these run slightly north of west, tapping the vein near its southern end. The highest, known as the Capel crosscut, cuts the vein, which runs S. 30° W., at 150 feet below the outcrop at a slight incline. An incline shaft connects this crosscut with the lower levels, and through this the mine has been worked to a depth of 820 feet. From the upper workings profitable stoping has been carried on.

As in the Golden Fleece, Vermont, and many other mines, the difficulty of handling water and the added expense of mining at depth led to the driving of a long adit tunnel. Part of the long tunnel of the Golden Fleece mine adjoining this property on the south served for both mines. From this adit at a point 1,950 feet from the mouth, a branch known as the De Camp crosscut was driven, tapping the Black Crook vein 1,200 feet below the outcrop. This tunnel was then connected with the upper workings by a raise on the vein. Below this tunnel level a winze 100 feet deep was sunk and 240 feet of drifting was done. The results obtained by this deep and expensive work have been uniformly disappointing in this, as in the other mines of the district. The amount of drifting and stoping may be seen from the map of the workings (Pl. VIII) and the longitudinal section (fig. 24).

Country rock.—The country rock, in which the Ilma and Gold King veins of the Black Crook mine occur, belongs to the same series of bedded flow breccias and tuffs that are found in the Golden Fleece mine. The beds dip 15° to 40° E. and the veins intersect them at right angles. (See fig. 25.) In the upper levels the tuff is weathered into a yellowish-white banded rock whose stratified nature is so well developed as to strongly resemble sandstone. The beds vary from half an inch or less to 5 or 6 inches in width. None of the coarse agglomerate noticed in the Golden Fleece mine was seen in the Black Crook. Interstratified with the layers of tuff are denser though often equally well banded flow breccias, which when noted in the deeper mine workings are greenish or brownish gray in color and can not easily be confused with the tuff. These flow breccias are much more extensively developed on the Golden Fleece tunnel level than in the upper workings of the mine.

Veins.—The Black Crook mine owes the major part of its production to a single vein known as the Ilma vein. Other minor veins and branches have been somewhat explored, and a little ore has been



Showing the vein here assumed.

found along the Black Crook fault, but its amount has been trifling. The Ilma vein strikes nearly north and south; it shows many local deviations, and these are often sharply angular, as is the case with nearly all the Lake City fissures, but the average direction is remarkably straight.

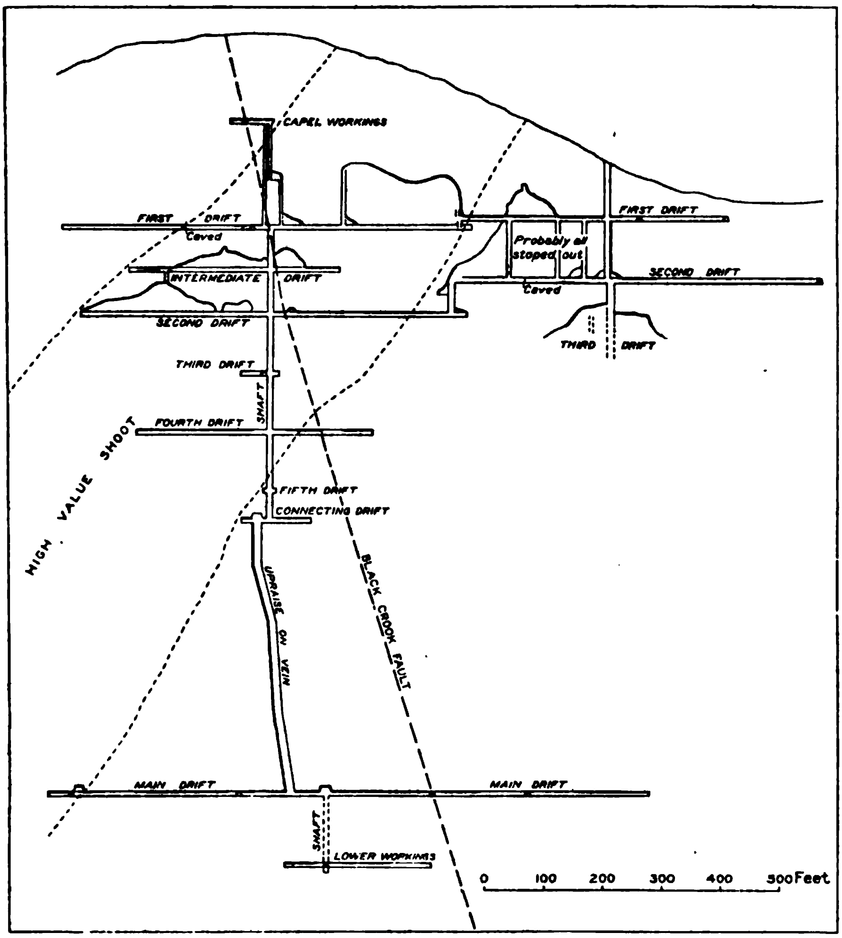


FIGURE 24.—Longitudinal section on plane of Black Crook vein.

The dip is toward the west. At the surface it was 70°, shallowed to 50° and 45°, then steepened again to 58°, which is its inclination in the lowest workings, 1,300 feet below the surface.

The vein has numerous branches, most of which make out from the hanging wall. (See fig. 25.) The foot wall is much more regular and is frequently separated from the vein filling by a strong layer of selvage clay; this, however, is not constant. The vein is not a simple filled fissure, but rather a series of sheeting planes, in many places brecciated, which have been replaced by ore and gangue minerals so as to form what Ransome has termed a lode fissure. From one extreme, where all ore shows evidence of formation by replacement, to the other, where a narrow and well-defined filled fissure occurs with no discernible replacement, this vein furnishes examples of nearly all gradations.

The mineralized zone has a width of from 4 to 8 feet through much of the mine, but only in the older and more profitable stopes did this width pay for extraction, and then only in exceptional cases. The pay streak in the ore, where the mineralization had been most intense and the filling least confused by waste rock, averaged throughout the mine about 18 to 20 inches.

Fault.—The Ilma vein is faulted by a well-defined east-west dip fault, called the Black Crook fault on account of its having been first observed on the Black Crook claim. This fault dips 73° W. and has a reverse throw as it offsets the north end (the hanging-wall side of the fault) of the Ilma vein about 35 feet to the west on each successive level. The fault is evidently later than the vein, as it is mineralized only where secondary oxidation and enrichment processes have been active since surface alteration of the vein began.

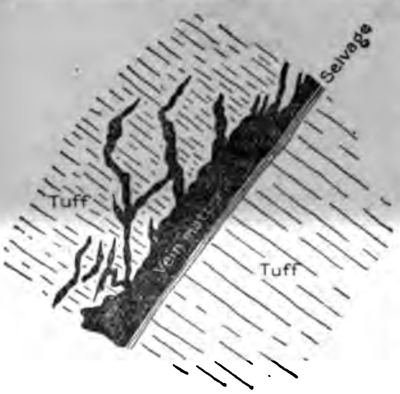


FIGURE 25.—Type of fissure in Black Crook (Ilma) mine.

Ores.—The ore of the Black Crook consists of sphalerite, galena, a little tetrahedrite, pyrite, and very subordinate chalcopyrite with irregular bunches of pyrargyrite in a gangue of quartz, barite, and rhodochrosite. The pyrite usually is in small amount in the ore, though it frequently impregnates the country rock and is then present in well-defined cubical crystals. The most constant mineral is sphalerite, which is but rarely absent in any of the ore and in some stopes is so abundant that the term "zinc stope" has been applied to them. It is usually of the coarse cleavable variety and contains enough iron and impurities to make it rather dark in color. An average of 158 samples taken on all levels of the mine showed 3.20 per cent lead and 15 per cent zinc; this gives a fair idea of the general content of the ore in sphalerite and galena. Dark ruby silver, pyrargyrite (Ag_3SbS_3), occurs in bunches through the ore and its relations to the other ore clearly prove it to be secondary as it coats cracks and fractures in the ore, especially that which runs high in the argentiferous tetrahedrite. Enrichments by pyrargyrite occur in even the lowest workings of the mine, 1,300 feet below the outcrop, but their number is greatly diminished.

The silver values were contained primarily in the galena and tetrahedrite, chiefly in the latter, but have been redistributed as native silver and pyrargyrite by the action of oxidation and secondary enrichment. In the oxidized ore of the upper workings a very considerable amount of native silver was found.

Banding is not very well developed, as the ore is chiefly massive, irregular, and filled with innumerable horses and fragments of country rock. Where it is at all well marked it is the result of the replacement of sheeted rock rather than of the successive deposition of minerals in open space.

A peculiar brownish-green, massive, fine-grained pyrite, locally known as "brown iron," was found in most of the upper workings of the mine, and is said to have run very high in gold. Four specimens of this ore left for only a few weeks in paper trays completely corroded the paper by the uncombined sulphuric acid, showing the ore to consist of sulphates, sulphuric acid, and pyrite. Probably much of this pyrite is secondary and the high values in gold were undoubtedly the result of secondary concentration. It does not occur below the upper workings of the mine. There is little or no question that the workable values of the Black Crook ore have been entirely produced by oxidation and secondary enrichment, for the lower workings show only primary minerals in small amount and low values. All of the rich minerals are of characteristic secondary types, and extensive exploration has failed completely to show values that justify the continuation of mining operations. The width of many of the stopes may also indicate that secondary minerals have been deposited not only within the area of the original vein minerals, but also in the wall rock, which they may have invaded and replaced in their downward progress, materially increasing the ore masses both in size and in richness of contained values.

The paragenesis of the primary minerals, here as elsewhere, is obscure, but the metallic minerals seem to have been among the earlier formed, and of these the sphalerite and galena seem older than the richer tetrahedrite. The pyrargyrite and native silver are unquestionably secondary.

The ore in the mine, even with the aid of the assay plan kindly furnished by the management, does not show any well-defined localization. If such localization exists, it has somewhat the position shown in figure 24.

To the writers the evidence seems conclusive that further exploration in depth on this vein would fail to reveal any bodies of ore that could meet the expense of development.

The average value of the ore in the Black Crook mine is difficult to determine, as no authentic records of the earlier work could be secured. Much of it was undoubtedly high grade, as shown by the mint report for 1884. During three months' active production in that year the mine yielded 1,277 tons of ore, valued at $124,447, an average of $97.21 per ton. Statements of the superintendent put the average yield of this upper ore at 21 ounces silver and 3 ounces gold. Much very high-grade ore was undoubtedly included in this average, for many small bonanzas and bunches of secondary ruby silver yielded from $200 to $600 per ton and in instances gold values ran as high as 12 to 15 ounces, but the average seems to be fairly close to $100 per ton.

With increase in depth, the value of the ore fell off rapidly, much of it averaging not more than $35 per ton in gold and silver. A careful sampling recently made shows that the average value of the ore now remaining in the mine is much below the bonanza values of its early operation.

The values in the ore show no relation to the Black Crook fault, as the higher values occur more frequently at a distance from it than in its immediate neighborhood. If any connection can be detected at all, it is in the direction of impoverishment and not of enrichment.

SOUTH FORK OF HENSON CREEK.

MORO.

The Moro mine (see fig. 26) is located about 1½ miles in a direction S. 60° E. from Capitol City. The mine is operated by the Hanna Mining & Milling Co. The openings are on the Moro claim on the south side of a small east-west gulch, which heads westward from the South Fork of Henson Creek.

Equipment.—The Moro is connected with Capitol City by a trail about 1½ miles long, over which supplies are brought to the mine. Recently a wire-rope tramway was installed, connecting the mine openings with the mill in the bed of the South Fork of Henson Creek, 1,200 feet below the mine and at the mouth of the gulch in which the mine is located. The ore was formerly shipped to the smelter, but it is now treated in the mill owned and operated by the company. The mill has a capacity of 100 tons per 24 hours, and treats not only the ores mined in the company's own property, but also undertakes custom work from the mines in the neighborhood of Capitol City. In 1906 this mill was much enlarged, and now contains rolls, Huntington mills, concentrating tables, slimers, a system of settling tanks, and a Blake-Morscher static electric machine for handling the zinc concentrates. Power is supplied by the Capitol City Power & Electric Co.

Development.—A fissure vein worked in the mine is opened by three tunnels which run into the hill in a direction about S. 15° W., and connect with the first, second, and third levels, respectively. (See diagram, fig. 27.) The first, or uppermost, level opens directly on the vein and runs into the hill for 500 feet; 200 feet from the mouth it connects with an old shaft, by means of which the vein was first operated. The second level has been driven 71 feet below the first, directly on the vein; it runs into the hill for 570 feet. The third, or lowest, level is 126 feet below the second. For the first 75 feet it runs S. 60° W. and cuts through barren rock; it then encounters the vein and runs along it for 700 feet. At a point 200 feet from the breast the third level is connected with the other two levels by an inclined raise on the vein. A number of short drifts have also been run on branch veins on the third level.

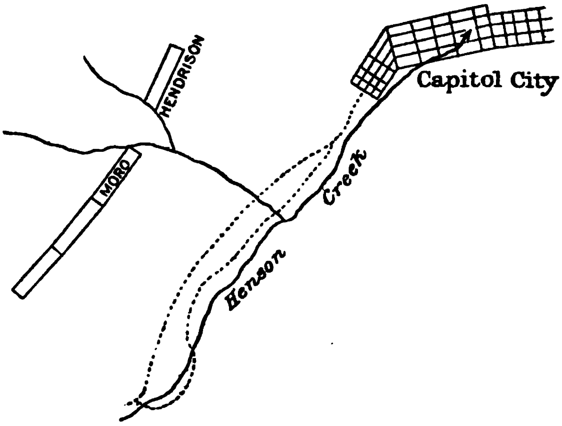


FIGURE 26.—Sketch showing location of Moro and Hendrison claims.

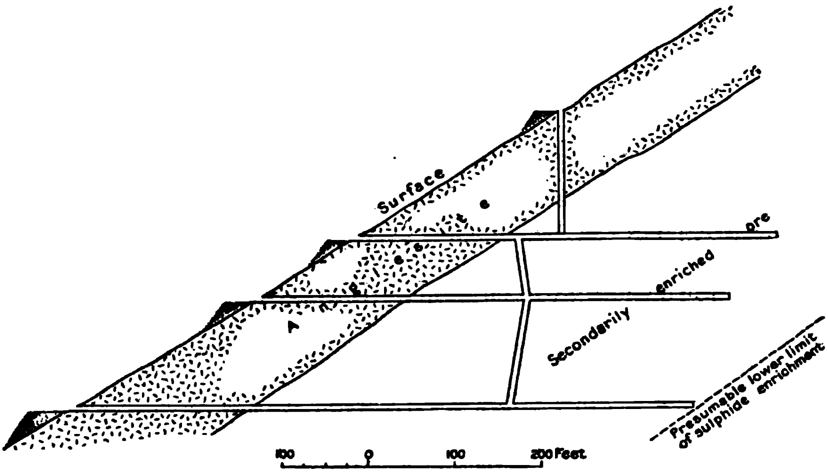


FIGURE 27.—Longitudinal section of the Moro mine, showing depth of anglesite alteration.

Country rock.—The country rock of the region consists of the lower members of the Picayune volcanic group of banded flow breccias. The banding is caused by the movement of the lava previous to consolidation. When fresh the flow lines can be seen only indistinctly and on close examination, but when weathered they become very prominent and may be seen to be caused by innumerable dark inclusions arranged with their longer axes in the direction of flow. The banding is generally horizontal or inclined at a very slight angle. The inclusions are usually darker and finer grained than the matrix of the rock, and undoubtedly represent the quickly chilled coating formed on the surface and later broken and included in the slowly moving lava mass. Many of them are markedly chloritized even at great distances from the site of mineralization. In some places this wall rock shows fewer flow lines, especially in the thicker members, and is characterized by well-marked porphyritic texture, caused by the presence of numerous small phenocrysts of plagioclase feldspar. The distribution of shoots and vein material in the mine is independent of the banding of the lavas, for there is no tendency toward a horizontal variation of mineral material; and it is therefore probable that the layers of andesite have had little or no effect on the ore deposition. Cross mentions (p. 23) a small exposure of granite at the mouth of the gulch near the mill, which indicates that the Picayune volcanic group is nearly cut through here by Henson Creek, and it is possible that this formation lies less than 1,500 feet below the lowest level of the mine.

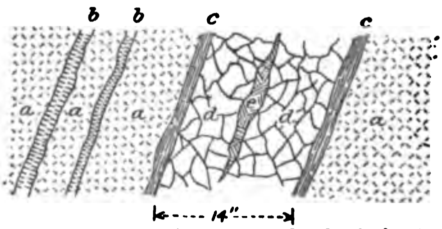


FIGURE 28.—Face of Moro tunnel, first level, showing structure of lode. *a*, County rock; *b*, quartz; *c*, clay selvage; *d*, galena and quartz; *e*, barite.

Vein.—The ore deposit is a typical fissure vein well defined and with clean walls in the upper levels, but becoming irregular and stringer-like in the lower levels.

The vein matter in the first level is contained between well-defined and quite smooth hanging and foot walls, but contains a great many angular fragments of wall rock. Some parallel stringers of quartz occur in the wall rock. (See fig. 28.) Locally the vein splits into stringers and includes too large quantities of wall rock to permit its profitable operation.

On the second level and to a still greater degree on the third level the vein is divided into many stringers, some of which make off into the foot wall as branches. On the third level the vein is so broken up into stringers that it is difficult to follow, and the crosscut intended to intersect it was extended far beyond it without recognition. Beyond the crosscut the vein consists of a series of veinlets en échelon running at about 10° to 15° to the general trend of the lode. (See fig. 30). The dip of the vein at the surface and on the first and second levels is 66° E., but this steepens to 78° on the third level. (See fig. 29.)

In strike the vein is extremely irregular, as may be seen from the plot of the workings (fig. 31). Most of the bends are quite angular as if caused by the intersections of branching fissures.

This vein is undoubtedly the same as that extensively worked on the north side of the gulch. Its total length, as worked on both properties, approximates 2,000 feet.

Ores.—The ore of this mine when unoxidized consists of galena, sphalerite, chalcopyrite, pyrite, and tetrahedrite in a gangue of white glassy crystalline quartz with subordinate barite. The galena is by far the most abundant mineral and constitutes the chief product of the mine. It is generally coarse, with single cubical cleavage masses up to an inch across, but in places it has the usually fine-grained appearance of steel galena. It is everywhere much crushed and often shows twinning due to stress. It is also generally characterized by curved cleavage faces. Many of the stopes consist of this coarse galena, with but little else present, although bunches of sphalerite occur here and there through it. The sphalerite varies from almost lemon yellow to nearly black and where present is usually intermixed with the chalcopyrite in the ore, indicating that it was precipitated simultaneously with that mineral. The argentiferous tetrahedrite is in far less amount than is common in the ores of this region, showing only here and there through the ore. The metallic minerals of the ore are often much shattered and cut by innumerable little veinlets of white glassy quartz, which frequently show a very perfect comb structure and form inclosing crusts around the shattered fragments. (See fig. 32.) Between the combs of quartz are thin bands of a reddish mineral, apparently hematite, which form a delicate tracery that seems to much emphasize the banded nature of these crusts. It is stated by the management that where these fine reddish crusts are present the ore generally contains notable values in gold, and it may be that the increased gold values and reddish

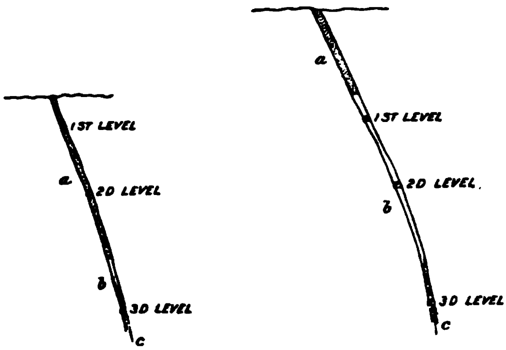


FIGURE 29.—Cross sections of the Moro vein on lines indicated in figure 31. *a*, Anglesite in zone of oxidation; *b*, primary ore; *c*, fraying out of vein on third level.

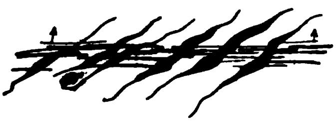


FIGURE 30.—Manner in which Moro vein crosses fissures diagonally on lower level.

mineral are both due to secondary precipitation. Vugs of considerable size and in large numbers are thus produced in the ore, and these are usually lined with white quartz crystals and some beautiful bladed crystals of barite.

The primary ore of the upper level stopes consisted almost wholly of galena, which carried an average silver content of 10 to 17 ounces. The chalcopyrite and sphalerite were most commonly associated with subordinate amounts of galena. The average yield of the lower-grade ore from the upper levels is stated to have been 10 to 17 ounces silver, 10 to 15 per cent lead, 4.4 per cent copper, and 6 to 15 per cent zinc, giving a total average value of $30 a ton.

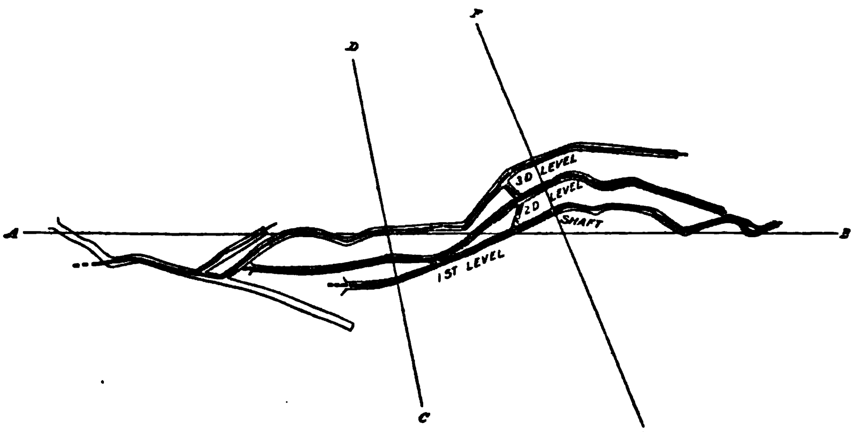


FIGURE 31.—Plan of workings of the Moro mine. (See fig. 29 for cross sections.)

This ore carried only very small and usually insignificant quantities of gold. The primary ore in the third level shows a marked change, containing much more chalcopyrite, pyrite, and sphalerite, and yielding correspondingly higher gold than the ore from the first and second levels. Some of the ore here assayed 0.5 to 3 ounces gold, 10 to 16 ounces silver, 7 to 30 per cent lead, 7 to 10 per cent zinc, and 2 to 4 per cent copper.

The primary vein filling is separated, in the upper levels, from the hanging and foot walls by a well-defined layer of selvage clay one-half inch to 3 inches in thickness, making the ore comparatively easy to mine.

Except that the quartz is of later origin than the metallic minerals the paragenesis can not be clearly made out. It seems probable that the barite is the later of the two gangue minerals as it comes often in bladelike crystals in cavities. Banding is not well developed in the metallic ore of the upper levels as the quartz runs through so much of the metallic ore in little veinlets, but a central vug filled with barite is often present. (See fig. 28.) In the lower levels banding is more prominent (fig. 33).

Secondary alteration.—The surface alteration of this vein is extremely interesting. Oxidation has altered the ore to a dense grayish-white noncrystalline anglesite ($PbSO_4$) for about 200 feet from the surface (see fig. 27); the carbonate, cerusite, is practically unknown in the mine. The anglesite in a quartzose gangue, extends in from the surface for 180 to 200 feet. The line which separates it from the sulphide ore is sharp and follows very closely the contour of the hill. As the sulphide zone is approached little nuclei of original primary galena may be seen in the ore, and the structural arrangement of the galena ore is perfectly preserved in the anglesite.

FIGURE 32.—Ore from the Moro mine, showing certain features of the paragenesis of the minerals. *sp*, Sphalerite; *ch*, chalcopyrite; *g*, galena; *q*, quartz; *h*, hematite.

Below the oxidized anglesite ore considerable enrichment of the ore by secondary copper sulphides is manifested by beautiful blue coatings of covellite on the fracture surfaces of the sphalerite. This sphalerite when fresh has a brilliant vitreous luster and yellowish-brown color, but when broken with a light tap of the hammer it falls to pieces along the innumerable fractures which were formed prior to the secondary deposition. These are so completely coated with covellite that it is at first difficult to distinguish it from that mineral, but when care is taken to break into the mineral itself along cleavage planes not previously opened its true character is apparent.

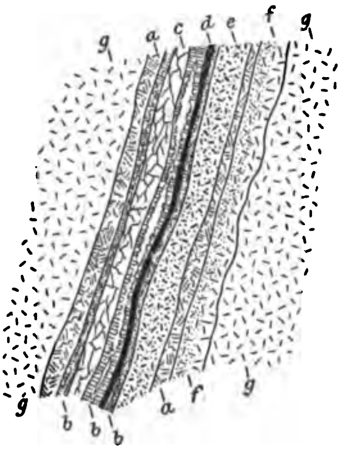


FIGURE 33.—Face in the Moro tunnel, showing structure of lode. *a*, Massive galena and quartz, irregularly mingled; *b*, quartz veinlets with well-developed comb structure; *c*, altered country rock with veinlets of galena and quartz; *d*, narrow band of intensely silicified country rock now altered to aggregate of quartz granules; *e*, blackened silicified country rock; *f*, darkened and partly altered country rock; *g*, andesite flow breccia.

Considerable black sooty chalcocite is also deposited in the ore, but this is confined almost wholly to fractures and cavities in the chalcopyrite, while pyrite is confined to some surfaces of the galena. Some of the sphalerite is also covered along fracture planes with a gray coating which is believed to be galena but which, because of its fine grain, is difficult to identify positively even under the high powers of the microscope. The minerals indicate that the workings of the mine have not yet penetrated below the zone of surface alteration, but already the vein, like others in the district, shows not only marked impoverishment even in the 500 feet of vertical distance so far disclosed, but also every indication of fraying out and disappearing. It holds no greater promise of profitable deep exploration than do the other veins.

HENDRISON CLAIM.

The Hendrison workings are directly north of the Moro on the opposite side of the gulch. The vein is unquestionably a continuation of the Moro and is in every respect similar to it. A tunnel has been run on the vein for 400 feet. The ore carries a higher content of zinc than that portion of the vein worked in the Moro and is also very much more noticeably enriched by pulverulent secondary chalcocite.

PROSPECTIVE GOLD AREA.

Some exploration for gold is being carried on. The Sunshine Lode in Larson Creek is said to show assay values of from $1 to $10 per ton, but as no shipments have been made, it is not possible to say just what value can be placed upon these assays. The lode itself does not look very promising, but has not been developed enough to disclose its true value. The Golden Crown prospect and others in the area are practically undeveloped, and so little can be said of them, except that they are very narrow veins of quartz, showing few metallic minerals and these chiefly pyrite. The T. C. M. Tunnel is being driven to cut at depth several veins which outcrop near Larson Creek, but at present (1908) only reported assays showing total values from $1 to $6 in lead, silver, and gold, can be cited. No shipments have been made. The outcrops do not appear to be very highly mineralized, although greatly decomposed.

BIBLIOGRAPHY.

There are few publications on the Lake City district. The following bibliography includes practically all of the literature bearing directly on the region:

1874 to present. Engineering and Mining Journal, weekly publication. Many notes, usually from correspondents, on the history, development, production, etc., of the Lake City mining district.

1880. Emmons, S. F., Tenth Census, vol. 13, p. 86. Gives a table showing kind of country rock, ore, and gangue minerals, and dip and strike of veins in eight mines in Hinsdale County.

1887. Comstock, T. B., Geology of vein structure of southwestern Colorado. Trans. Am. Inst. Min. Eng., vol. 15, pp. 218–265. Refers to the Lake City region in a very casual manner, giving no definite information on it.

1887, 1888, 1889, 1890, 1891, 1892. Reports of the Director of the Mint. Contain statistics of production of individual mines, 1887–1892; also brief notes on the operations, development, etc., of the various properties.

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1901–2. Report of commissioner of mines, State of Colorado, pp. 93–97. Gives brief sketch of history, geology, mines, and minerals of Hinsdale County.

1903. Rickard, T. A., Across the San Juan Mountains, pp. 72–77. Contains a description of the Golden Fleece mine, Hinsdale County.

1904. Irving, J. D., Ore deposits in the vicinity of Lake City, Colo. Bull. U. S. Geol. Survey No. 260, pp. 78–84. Gives brief account of the mining district and a short sketch of the history, geology, and ore deposits.

1880–1908. Mineral Resources of the United States. Contains a few references to mines in Hinsdale County, during various periods.

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 479

THE GEOCHEMICAL INTERPRETATION OF WATER ANALYSES

BY

CHASE PALMER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1911

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ILLUSTRATION.

THE GEOCHEMICAL INTERPRETATION OF WATER ANALYSES.

By CHASE PALMER.

EXPRESSION OF CHEMICAL ANALYSES.

Terrestrial waters are essentially solutions of a few salts, and their chemical character, like that of solutions in general, depends on the nature and proportion of the substances they contain. The interpretation of the chemical character of a water from the results of analysis is necessarily uncertain and unsatisfactory if it is based merely on the amounts of the radicles determined. In analytical chemistry, as in other branches of the science, the chemist considers the inherent properties of the radicles of substances, and hence his statement of the results of a water analysis should be framed in accordance with the chemical nature and the proportional amounts of the radicles determined in a solution of mixed salts. There is no lack of information concerning the amounts of the various materials dissolved in natural waters and the mutual relations of their parts. What the chemist especially needs is a form of statement that will adequately express these relations and disclose the true proportions of the radicles.

The engineer has always recognized the importance of determining the properties of water without recourse to complete chemical analysis, and his attention is naturally directed to those properties which are objectionable. In 1841 Thomas Clark patented in England a process for removing the objectionable constituents of hard waters. The softening agent used by Clark was lime water, the action of which depends on a very simple principle. In contact with lime water the soluble calcium bicarbonate in hard water is changed to insoluble calcium carbonate and precipitated, the hardening constituent, calcium, being removed simultaneously from the hard water and from the softening agent.

The reaction may be expressed by the equation—

$$CaH_2(CO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O$$

This process of improving the quality of water at once acquired wide popularity. In response to many requests for information respecting his methods of examining waters, in 1847 Clark [1] addressed

[1] Clark, Thomas, On the examination of water for towns, for its hardness, and for the incrustation it deposits on boiling: Chemical Gazette, vol. 5, 1847, p. 100.

to friends a circular letter in which he states that his examination of waters involves two processes—one for ascertaining the hardness of water and one for ascertaining its alkalinity. The degrees of permanent hardness, temporary hardness, permanent alkalinity, and acidity are now capable of exact measurement by methods which do not involve the determination of the constituents of water. In the section on the properties of water definite limits, deducible from the results of a complete chemical analysis, will be set to the special properties. The limits there assigned conform to the measurements of hardness and alkalinity if made according to the exact method of Hehner as described by Sutton.[1] The acidity of water may be determined by direct measurement, made by neutralizing a known quantity of the acid water by a standard alkaline solution. Saltness caused by dissolved neutral salts is a general property of natural water. Since the alkalies and strong acids contribute largely to this property, it is essential that the proportional amounts of the alkalies and strong acids be separately determined. From the data thus obtained, the full value of the salinity—the saltness—of water may be determined.

It is to be observed that Clark fully recognized the propriety of looking to some of the properties of water for information concerning its fitness for domestic and industrial uses, and the benefit of his invention to modern civilization is beyond estimate. In problems involving the chemical action of water it is important to-day that the student consider all the properties conferred on water by all the substances dissolved in it, for in the totality of its properties lies the full power of water as a chemically active agent.

Two forms of stating the amounts of mineral materials dissolved in water have been widely used. These forms are typified by the following analysis of sea water:[2]

Composition of ocean water.

Amounts assigned to hypothetical combinations.		Amounts assigned to radicles.	
Combinations.	Milligrams per liter.	Radicles.	Milligrams per liter.
Sodium chloride ($NaCl$)	27,215	Sodium (Na)	10,710
Magnesium chloride ($MgCl_2$)	3,807	Potassium (K)	390
Magnesium sulphate ($MgSO_4$)	1,658	Calcium (Ca)	420
Calcium sulphate ($CaSO_4$)	1,260	Magnesium (Mg)	1,300
Potassium sulphate (K_2SO_4)	863	Sulphate (SO_4)	2,700
Magnesium bromide ($MgBr_2$)	76	Chloride (Cl)	19,350
Calcium carbonate ($CaCO_3$)	121	Bromide (Br)	60
		Carbonate (CO_3)	70
	35,000		35,000

[1] Volumetric analysis, 9th ed., p. 70.

[2] Mean of 77 analyses, by W. Dittmar, of sea water collected by the Challenger expedition: Challenger Report, Physics and chemistry, vol. 1, 1884, p. 203.

The older form, which represents the radicles as grouped together in arbitrary combinations, has by no means lost all adherents. It seems to be held in especial favor by the engineer because it gives the amount of dissolved material in terms which enable him to determine the corresponding amounts of substances necessary to fit a water for special industrial uses. The geologist, however, long ago realized that this form of expressing the chemical character of a water is inadequate to the exacting demands of research and has resorted to the form of statement in which the amounts of the radicles determined are given as independent units. In other words, he has practically abandoned a form of chemical expression and has adopted instead a statement of physical results. Chemical literature furnishes abundant evidence that the statement of water analyses in a form which does not recognize the *proportional reaction capacity* of the radicles fails to show the chemical character of the waters. Waters differing widely in character may be grouped together as similar if the classification is based on the preponderance of any radicle that may be considered as dominant in a solution of salts or on the apparent predominance of two or more radicles selected merely because they contribute largely to the weight of the mixture. Such classifications may be interesting from several points of view, but they are unreliable guides to the solution of geologic problems involving chemical processes. Furthermore, chemists, whose attention is fixed on the physical weights of the radicles, which are assumed to be free and independent, may easily fail to observe important facts concerning the chemical character of waters, especially facts relating to geology.

One advantage of the ionic form of stating water analyses is that it assigns weights directly to the chemically active parts of the dissolved substances instead of using those parts to build imaginary structures. The statement of the amounts of the radicles, however, indicates only the chemical composition of a water, not its character, for the *physical weight* of a radicle is no criterion of its *chemical value* in a system of dissolved salts such as exists in water. On the other hand, if the radicles are considered not as matter subject only to the law of gravitation, but rather as individuals acting together under the law of equivalent combining weights, contributing their proportional shares to the final balance of the system, the meaning of the results of a mineral analysis of water can be expressed clearly and precisely.

The reaction capacities of the radicles of the salts dissolved in water are the quotients obtained by dividing the weight of each radicle by its corresponding equivalent combining weight. The reaction capacity may be more logically determined by using for factors the reciprocals of the equivalent combining weights of the radicles, according to the practice of Herman Stabler, in interpreting the results of water analyses for industrial purposes.[1] Stabler defines "reaction coefficient" as the chemical reacting power of a unit weight of a radicle. The reaction coefficient of a radicle is the ratio of the reaction capacity of 1 part of that radicle to the reaction capacity of 8 parts of oxygen and is computed as follows:

	Atomic weights.	Equivalent weights.	Reaction coefficient.
Oxygen	16	$\frac{16}{2}=8$	1
Hydrogen	1.008	1.008=1.008	$\frac{1}{1.008}=0.992$
Calcium	40.09	$\frac{40.09}{2}=20.045$	$\frac{1}{20.045}=.0499$
Magnesium	24.32	$\frac{24.32}{2}=12.16$	$\frac{1}{12.16}=.0822$

The other reaction coefficients are similarly obtained.

The product of the "reaction coefficient" by the amount of a radicle Stabler calls the "reacting value" of that amount of the radicle. These terms are peculiarly adapted to the chemical valuation of radicles determined in mixtures, and they will be adopted here in the chemical classification of waters. The following table shows the positive and negative radicles usually found in surface waters and their reaction coefficients:

Positive and negative radicles, with reaction coefficients.

Positive radicles.	Reaction coefficients.	Negative radicles.	Reaction coefficients.
Hydrogen (H)	0.992	Carbonate (CO_3)	0.0333
Ferrous iron (Fe)	.0358	Bicarbonate (HCO_3)	.0164
Aluminum (Al)	.1107	Sulphate (SO_4)	.0208
Calcium (Ca)	.0499	Chloride (Cl)	.0282
Magnesium (Mg)	.0822	Nitrate (NO_3)	.0161
Sodium (Na)	.0435		
Potassium (K)	.0256		

Stabler prefixes the letter *r* to the symbol of a radicle to designate the reacting value of the radicle, and the same symbolization will be used in this report.

Under the name "milligram equivalents" (that is, equivalents of milligrams of hydrogen) chemists have long used the reacting values of the radicles for two purposes—namely, to determine the accuracy of the analysis of a water and to obtain reliable factors to be used in the construction of hypothetical combinations. Stabler has shown that the reacting values may be put to a better use, for he has demonstrated mathematically that the analytical results can be

[1] Stabler, Herman, The mineral analysis of water for industrial purposes and its interpretation by the engineer: Eng. News, vol. 60, 1908, p. 356. Also, chapter on the industrial application of water analyses in Water-Supply Paper U. S. Geol. Survey No. 274, 1911, pp. 165–181.

interpreted far more satisfactorily directly from the reacting values than from their hypothetical combinations, and he has shown that the labor of calculating the amounts of remedial agents required to produce desired changes in the character of a water is thereby reduced to a minimum.

CHEMICAL CHARACTER OF WATER.

BASE DATA.

The investigation of the surface waters of the United States, concluded in 1908 by the water resources branch of the United States Geological Survey, has accumulated a store of information concerning the amounts of inorganic material contained in the river waters of the country. During the progress of the investigation the writer studied the composition of the water of many rivers, and though he observed great diversity in the composition of the waters, he was convinced that the waters in one locality could not be differentiated in chemical character from the waters in other localities if the analytical results were stated in amounts of the radicles determined. He is satisfied, however, that the statement of the radicles can be used satisfactorily for interpreting the character of water solutions if the chemical values involved are made the basis of interpretation, and he therefore presents for consideration the chemical classification of waters here described. To illustrate the principle on which the new classification is based the results of analyses of the water of Lake Champlain will be used, and one of the properties of the water will be deduced by direct resort to the chemical values of the radicles contained in it.

WATER OF LAKE CHAMPLAIN.

The average results of analyses[1] of four separate samples collected at four different points on Lake Champlain are shown below.

Results of four analyses of water of Lake Champlain.

Analytical results.		Interpretation of results.		
Radicles.	Parts per million.	Reaction coefficients.	Reacting values (equivalent to milligrams of hydrogen).	
Na (K)	6.1	0.0435	0.264	
Ca	14.0	.0499	.699	
Mg	2.3	.0822	.230	
Fe	.76	.0358	.027	1.22
CO_3	31.0	.0333	1.032	
SO_4	7.4	.0208	.154	
Cl	1.2	.0282	.034	1.22
Colloids (SiO_2)	3.76	"Concentration value" (milligrams of hydrogen per liter)		2.44
Total dissolved	66.52			

[1] Leighton, M. O., Preliminary report on the pollution of Lake Champlain: Water-Supply Paper U. S. Geol. Survey No. 121, 1905, p. 20.

The weights of the radicles have thus been resolved to values which are chemically measurable by a common standard. The unit of measurement is the milligram of hydrogen, in conformity with the international acceptance of hydrogen as the standard of reaction capacity. At first sight the reacting values may seem insignificant, but they disclose an important quality of the water of Lake Champlain. The reacting value of the alkalies (0.264) exceeds the sum of the reacting values of the sulphates and chlorides (0.188) by 0.076. This excess of alkalinity may be expressed in terms of sodium carbonate by multiplying 0.076, its reacting value, by 53, the combining weight of sodium carbonate. The product, 4.02, represents the parts of sodium carbonate per million parts of water. Surface waters distinguished by alkalinity due directly to the alkalies are not usually found in drainage basins whose rocks consist entirely of calcareous formations. The excessive alkalinity suggests that the lake receives water that has come from the massive rocks of the mountains, and that these waters contain carbonates of the alkalies in quantity sufficient to overcome all the permanent hardness of the waters derived from more recent formations and to render the lake permanently alkaline.

CHARACTER FORMULA.

Different waters are solutions having different degrees of concentration, and the degree of concentration of the water from a given source is subject to continual change. The application of the reacting values of the radicles to the character of water is therefore restricted to the particular water and to that water at the time it was sampled for analysis.

If, however, the reacting values are expressed in terms from which the concentration factor is omitted they become capable of wide application. Such an expression may be considered the character formula for the mixture of salts dissolved in a water. For convenience 100 has been selected as the formula weight, and the reacting value of each radicle in the formula is therefore expressed as a per cent of the concentration value. This formula weight has been found to be applicable to the many waters that have come under the writer's observation. Thus the character formula not only shows at a glance the chemical proportions of the radicles found in a water, but also clearly discloses even slight differences in the proportions of the radicles in waters under comparison, as may be seen by comparing, for example, the character formulas of the waters cited in Table 1, opposite page 14. The changes, moreover, in the chemical proportions of the radicles present in a river water at different stations along its course are brought out in strong relief by the use and application of this formula. These changes are shown in the tabulated character formulas of the Mississippi River water at the several stations from Minneapolis to New Orleans. The character formula adopted for the comparative study of water is strictly a chemical formula. It invokes the support of no hypothesis, but rests solely on the fundamental law of equivalent combining weights.

In order to show the chemical character of mineral waters with especial reference to their therapeutic action, Carl von Thàn[1] many years ago devised a form of expression that was also based on the law of equivalents. Von Than's expression involved two separate ratings, one for the reacting values of all the positive radicles and one for the reacting values of all the negative radicles, the basis of each rating being 100. This double rating makes the resulting expression too cumbrous for ready interpretation. The character formula here proposed refers the reacting values of all the radicles in the system of dissolved salts to one aggregate, so that the characterization of the water solution is greatly simplified.

PROPERTIES OF NATURAL WATERS.

Nearly all terrestrial waters have two general properties, salinity and alkalinity, on whose relative proportions their fundamental characters depend. Salinity is caused by salts that are not hydrolyzed; alkalinity is attributed to free alkaline bases produced by the hydrolytic action of water on solutions of bicarbonates and on solutions of salts of other weak acids.

All the positive radicles, including hydrogen, may participate in producing salinity; but of the negative radicles only those of the actively strong acids can perform a similar function. The principal strong acids in natural waters are represented by the sulphates, chlorides, and nitrates. Since salinity depends on the combined activity of equal values of both positive and negative radicles, and since its degree is limited only by the reacting values of the strong acids, the full value of salinity is obtained by multiplying the total value of the strong acid radicles by 2.

The full value of alkalinity and at the same time due recognition of the parent substances which are the source of alkalinity can be obtained by doubling the values of the bases in excess of the values of the strong acids.

The positive radicles determined in a water analysis, in accordance with their properties, fall naturally into three groups, as follows:

Group *a*. Alkalies (sodium, potassium, lithium). Their salts are readily soluble in water. They do not cause hardness.

Group *b*. Earths or alkaline earths. Calcium and magnesium are the chief representatives of this group. Many of their salts are

[1] Sitzungsberichte der Kaiserl. Akad. der Wissenschaften [Vienna], Band 51, 2te Abtheilung (1865), p. 347.

sparingly soluble in water. They cause the property commonly known as hardness.

Group *c*. Hydrogen. Salts of hydrogen are acids and cause acidity in waters.

The groups of positive radicles are measured by the sum of the reacting values of their members, and in accordance with the prevalence of the reacting values of the groups of positive radicles in the system, five special properties are possible, namely:

1. Primary salinity (alkali salinity); that is, salinity not to exceed twice the sum of the reacting values of the radicles of the alkalies.

2. Secondary salinity (permanent hardness); that is, the excess (if any) of salinity over primary salinity, not to exceed twice the sum of the reacting values of the radicles of the alkaline earths group.

3. Tertiary salinity (acidity); that is, the excess (if any) of salinity over primary and secondary salinity.

4. Primary alkalinity (permanent alkalinity); that is, the excess (if any) of twice the sum of the reacting values of the alkalies over salinity.

5. Secondary alkalinity (temporary alkalinity); that is, the excess (if any) of twice the sum of the reacting values of the radicles of the alkaline earths group over secondary salinity.

In distinguishing the special properties, the values of radicles of the same sign are doubled. By this procedure the positive and negative radicles, which together induce the special properties, receive their full value. The use of the adjectives "primary" and "secondary" to qualify the general properties of the water solution associates naturally the alkalies with the oldest rock formations, of which the alkalies are the principal soluble decomposition products, and refers the alkaline earths to the more recent formations as their principal sources.

The character of natural waters with reference to the lithology of the region from which they are derived, to their solvent action on minerals with which they may come in contact, to sedimentary deposits that they are likely to form, to their effect on industrial processes, and to their chemical action in general can best be portrayed by a statement of as many of the five special properties above mentioned as may be found, expressed in percentages of their totality.

CLASSIFICATION OF WATERS.

FORM OF STATEMENT.

The reaction properties of the water solution are fixed by the relative values of three of the five groups of radicles producing the five special properties of natural waters. The numerical relations of the value of the group of strong acids to the values of groups of positive radicles have been made the basis of the following classification.

Let a, b, d represent, respectively, the percentage values of the alkalies, earths, and strong acids. Any one of five conditions may exist: d may be less than a; equal to a; greater than a and less than $a+b$; equal to $a+b$; or greater than $a+b$. The five classes of waters resulting from these conditions are given below, with their attendant properties of reaction.

CLASS 1.

(d less than a.)

$2d$...........Primary salinity.
$2(a-d)$......Primary alkalinity.
$2b$...........Secondary alkalinity.

CLASS 2.

(d equal to a.)

$2a$ or $2d$......Primary salinity.
$2b$...........Secondary alkalinity.

CLASS 3.

(d greater than a; d less than $a+b$.)

$2a$...........Primary salinity.
$2(d-a)$......Secondary salinity.
$2(a+b-d)$...Secondary alkalinity.

CLASS 4.

(d equal to $a+b$.)

$2a$...........Primary salinity.
$2b$...........Secondary salinity.

CLASS 5.

(d greater than $a+b$.)

$2a$...........Primary salinity.
$2b$...........Secondary salinity.
$2(d-a-b)$...Tertiary salinity (acidity).

To dispel any perplexity that may possibly exist in the minds of those unfamiliar with the mode here used of expressing chemical values that are numerically coordinate, the relations of the properties of water to the reacting values of the radicles are stated again in a slightly modified form.

CLASS 1.—*Strong acids less than alkalies.*

(d less than a.)

Property values.		Reacting values.		
½ Primary salinity	=	Strong acids	=	d
½ Primary alkalinity	=	Alkalies−strong acids	=	$a-d$
½ Secondary alkalinity	=	Earths	=	b
Hence:				
Total salinity	=	Strong acids×2	=	$2\,d$
Total alkalinity	=	(Bases−strong acids)×2	=	$2\,(a+b-d)$

CLASS 2.—*Strong acids equal to alkalies.*

(d equal to a.)

Property values.		Reacting values.		
½ Primary salinity	=	Alkalies	=	a or d
½ Secondary alkalinity	=	Earths	=	b
Hence:				
Total salinity	=	Alkalies×2	=	$2\,a$ or $2\,d$
Total alkalinity	=	Earths×2	=	$2\,b$

CLASS 3.—*Strong acids greater than alkalies, and less than bases*

(*d* greater than *a*; *d* less than $a+b$.)

Property values.	Reacting values.	
½ Primary salinity	=Alkalies	$=a$
½ Secondary salinity	=Strong acids—alkalies	$=d-a$
½ Secondary alkalinity	=Bases—strong acids	$=a+b-d$
Hence:		
Total salinity	=Strong acids ×2	$=2\ d$
Total alkalinity	=(Bases—strong acids)×2	$=2\ (a+b-d)$

CLASS 4.—*Strong acids equal to bases.*

(*d* equal to $a+b$)

Property values.	Reacting values.	
½ Primary salinity	=Alkalies	$=a$
½ Secondary salinity	=Earths	$=b$
Hence:		
Total salinity	=(Alkalies+earths)×2	$=2\ (a+b)$ or $2\ d$

CLASS 5.—*Strong acids greater than bases.*

(*d greater than* $a+b$.)

Property values.	Reacting values.	
½ Primary salinity	=Alkalies	$=a$
½ Secondary salinity	=Earths	$=b$
½ Tertiary salinity (acidity)	=Hydrogen	$=d-(a+b)$
Hence:		
Total salinity	=Strong acids ×2=2 *d*	

The form in which the analytical results are stated is especially serviceable in the practical study of water as a geologic agent. The statement shows: First, the properties of the solution in percentage proportions; second, the percentage reacting values of coordinate radicles, from which the properties of reaction may be directly derived, accompanied by a statement of concentration values in milligrams per liter; third, the character formula—the percentage reacting values of the individual radicles determined—together with a statement of the concentration value; fourth, the base analyses.

The amount of any radicle may be obtained by using the following formula:

$$\text{Radicle in milligrams per liter} = \frac{\text{Percentage value} \times \text{concentration value}}{100 \times \text{reaction coefficient}}$$

or, the amount of any radicle may be obtained by dividing the reacting value of the radicle by its reaction coefficient.

APPLICATION OF STATEMENT.

Waters representing these five classes are found in nature. Surface waters appear to belong chiefly to the first three classes, class 4 is represented in sea water and brines and class 5 is exemplified by mine waters and by waters of volcanic origin. Examples of waters representing these five classes are given in Table 1.

		Class 5. (d greater than a+b.)		
	…an water.[b]	Youghiogheny River at McKeesport, Pa.		
				Properties.
	Per cent.	*Per cent.*		
Primary	78.6	14.7		Primary salinity.
Seconda…	21.1	68.6		Secondary salinity.
Tertiary	.0	16.7		Tertiary salinity (acidity).
Primary	.0	.0		Primary alkalinity.
Seconda…	.3	.0		Secondary alkalinity.
	100.0	100.0		
R…				*Reacting values.*
Groups:	*Mg. per liter.*	*Per cent.*	*Mg. per liter.*	Groups:
Alk…	476.036	7.33	0.396	Alkalies.
Ear…	128.471	34.32	1.853	Earths.
Hy…	.0	8.35	.451	Hydrogen.
Str…	602.421	50.0	2.700	Strong acids.
We…	2.086	.0	.0	Weak acids.
C…	1,209.014	100.0	5.400	Concentration value.
Radicles	*Mg. per liter.*	*Formula.*	*Mg. per liter.*	Radicles:
r N…	466.021	6.48	0.350	r Na.
r K…	10.015	.85	.046	r K.
r N…	....	....	....	r NH_4.
r Ca…	21.203	21.33	1.152	r Ca.
r Mg…	107.268	10.30	.556	r Mg.
r Fe…	....	2.69	.145	r Fe.
r H…	....	8.35	.451	r H.
r S…	56.099	47.35	2.557	r SO_4.
r Cl…	545.583	2.33	.126	r Cl.
r N…	.739	.32	.017	r NO_3.
r H…	....	.0	.0	r HCO_3.
r C…	2.086	.0	.0	r CO_3.
C…	1,209.014	100.0	5.400	Concentration value.
B…				*Base analyses.*
Radicles	*…per million.*	*Parts per million.*		Radicles:
Sod…	710.0	[c]8.0		Sodium (Na).
Pot…	390.0	1.8		Potassium (K).
Am…	....	....		Ammonium (NH_4).
Calc…	420.0	23.0		Calcium (Ca).
Mag…	300.0	6.7		Magnesium (Mg).
Iron…	....	.7		Iron (Fe).
Sul…	700.0	123.0		Sulphate (SO_4).
Chl…	350.0	4.5		Chloride (Cl).
Nit…	....	1.1		Nitrate (NO_3).
Bic…	....	....		Bicarbonate (HCO_3).
Car…	70.0	....		Carbonate (CO_3).
Bro…	60.0	....		Bromide (Br).
Colloids:				Colloids:
Sili…	....	8.5		Silica (SiO_2).
Alu…	....	7.5		Alumina (Al_2O_3).
T…	…000.0	197.0		Total dissolved solids.

…22 parts H_2SO_4 per million.

[c] +Nitrite (NO_2).

The character of the waters of Shenandoah, Miami, Maumee, and Youghiogheny rivers is interpreted directly from the results of the analyses as reported in Water-Supply Paper 236 of the United States Geological Survey.

Oswegatchie River water.—Average of 15 analyses of composite samples made up of 10 samples collected on 10 consecutive days, collections taken from April 10 to September 9, 1907. Analysts, R. B. Dole, W. D. Collins, and Chase Palmer.

The properties of the Oswegatchie River water resemble closely those of the still waters of Lake Champlain, whose primary salinity is 15.4, primary alkalinity 6.3, and secondary alkalinity 78.3. Thus Lake Champlain, east of the Adirondacks, is receiving primary-alkaline waters from the mountains, and the Oswegatchie, flowing from the western slope of the mountains, is delivering primary-alkaline waters to the St. Lawrence.

Shenandoah River water.—Average of analyses of 36 composite samples. Samples collected daily from September 12, 1906, to September 9, 1907.

As the Shenandoah drains an area whose rocks comprise the older limestone formations, the peculiar character of this water is not surprising. Waters in which hardness coincides with alkalinity may be formed in other sections of the country by proper admixture of primary with secondary waters.

Miami River water.—Average of analyses of 34 composites. Samples collected daily from September 16, 1906, to September 17, 1907. The properties are those normal to the water of a river traversing sedimentary rocks. The alkalies are low and, as is common in river waters in regions of Carboniferous rocks, their reacting values exceed the reacting value of chlorine.

Maumee River water.—Average of analyses of 36 composites. Samples collected daily from September 9, 1906, to September 7, 1907. Salinity is a very prominent property of the water. The excess of the chlorine value over the value of the alkalies, as shown in the character formula, is abnormal for rivers fed entirely by surface streams. This peculiarity of the Maumee water is discussed on page 30.

Brine from Highland, Ill.—This water was collected in October, 1910, from a Madison County well 1,100 feet deep. The analysis, for which the writer is indebted to Dr. Edward Bartow, director of the Illinois State Water Survey, is an important contribution to the geology of deep-seated salt waters.[1] The relative importance of the minor constituents is well shown by the new form of interpretation. In the original statement, for instance, the calcium and magnesium radicles in milligrams per liter are reported to be Ca 708.1, Mg 444.0,

[1] For the chemical character of surface waters in Illinois, see W. D. Collins, The quality of the surface waters of Illinois: Water-Supply Paper U. S. Geol. Survey No. 239, 1910.

and in combinations the same radicles are distinguished as $CaSO_4$ 2115.5, $CaCO_3$ 212.0, $MgCl_2$ 1033.0, $MgSO_4$ 875.0. Under either form of statement the calcium, by reason of its superior weight, might be considered the dominant radicle; direct comparison of the chemical values observable in the character formula of this brine shows, however, that as a factor of property magnesium exceeds calcium by a narrow margin.

Youghiogheny River water.—The high acidity of the Youghiogheny indicates that the river receives water from coal mines. The mode of expressing acidity by the new system is in perfect accord with the mode of expressing other properties. Acidity can not be adequately expressed by the so-called ionic form of statement, which is intended to show merely the composition of the water, and not its properties.

INTERPRETATION OF ANALYSES.

Some examples, offered to illustrate the application of the principles on which the rational interpretation of water analyses is based, will now be presented.

The river waters belonging to the Piedmont Plateau and Coastal Plain will be described, the relation of the properties of river waters to geologic formations will be considered, the analyses of the waters of three great rivers will be interpreted in connection with a discussion of dissolved silica in flowing waters, some of the changes in the character of the water of Mississippi River will be noted, and finally the changes in the character of the waters of the Great Lakes will receive attention.

RIVER WATERS IN THE SOUTHERN STATES.

The area drained by the rivers of the Piedmont Plateau and Coastal Plain extends from James River, in Virginia, to Pearl River, in Mississippi, and comprises about 125,000 square miles. The waters studied were taken from rivers in Virginia, North Carolina, South Carolina, Georgia, Alabama, and Mississippi. In the beginning of the investigation of these southern waters several serious obstacles were encountered, and it is, therefore, advisable to limit the consideration of the chemical character of these waters to the analyses made in the later part of the investigation, when conditions were most favorable for obtaining reliable results.

Complete analyses of river waters in Southern States appear in Tables 2 and 3, one covering the south Atlantic coast rivers from the Piedmont Plateau and the other the Coastal Plain rivers tributary to the eastern Gulf of Mexico.

Ga.	Oconee at Dublin, Ga.		Ocmulgee at Macon, Ga.		
					Properties.
	Per cent.		*Per cent.*		
	25.6		26.2		Primary salinity.
	15.2		16.4		Primary alkalinity.
	59.2		57.4		Secondary alkalinity.
	100.0		100.0		
					Reacting values.
'iter.	*Per cent.*	*Mg. per liter.*	*Per cent.*	*Mg. per liter.*	Groups:
500	20.40	0.369	21.28	0.337	Alkalies.
313	29.60	.534	28.72	.455	Earths.
187	12.80	.231	13.07	.207	Strong acids.
526	37.20	.672	36.93	.585	Weak acids.
526	100.0	1.806	100.0	1.584	Concentration value.
liter.	*Formula.*	*Mg. per liter.*	*Formula.*	*Mg. per liter.*	Radicles:
428	16.63	0.300	18.31	0.290	r Na.
072	3.77	.069	2.97	.047	r K.
249	19.90	.359	17.24	.273	r Ca.
025	8.20	.148	9.72	.154	r Mg.
039	1.50	.027	1.76	.028	r Fe.
126	7.15	.129	6.63	.105	r SO_4.
048	4.21	.076	5.62	.089	r Cl.
013	1.44	.026	.82	.013	r NO_3.
513	37.20	.672	36.93	.585	r HCO_3.
113	.0	.0	.0	.0	r CO_3.
526	100.0	1.806	100.0	1.584	Concentration value.
					Base analyses.
	Parts per million.		*Parts per million.*		Radicles:
	6.9		6.8		Sodium (Na).
	2.6		1.9		Potassium (K).
	7.2		5.7		Calcium (Ca).
	1.8		[illegible].1		Magnesium (Mg).
	.75		.8		Iron (Fe).
	6.2		4.9		Sulphate (SO_4).
	2.7		3.0		Chloride (Cl).
	1.6		.8		Nitrate (NO_3).
	41.0		35.0		Bicarbonate (HCO_3).
	.0		.0		Carbonate (CO_3).
					Colloids:
	16.0		26.0		Silica (SiO_2).
	65.9		79.2		Total dissolved solids.
	14.0		14.0		Number of composites.
907.	May 15–Oct. 17, 1907.		May 7–Oct. 21, 1907.		Dates.

Table 3.—*Character of Coastal Plain river waters entering eastern Gulf of Mexico.*

[Analysts, R. B. Dole, W. D. Collins, and Chase Palmer.]

	Oostanaula at Rome, Ga.		Alabama at Selma, Ala.		Cahaba at Birmingham, Ala.		Tombigbee at Epes, Ala.		Pearl at Jackson, Miss.	
Properties.	*Per cent.*		*Per cent.*		*Per cent.*		*Per cent.*		*Per cent.*	
Primary salinity....	10.2		15.1		20.4		15.4		28.1	
Primary alkalinity..	20.3		10.6		4.6		11.6		14.5	
Secondary alkalinity	69.5		74.3		75.0		73.0		57.4	
	100.0		100.0		100.0		100.0		100.0	
Reacting values.										
Groups:	*Per cent.*	*Mg. per liter.*	*Per cent.*	*Mg. per liter.*	*Per cent.*	*Mg. per liter.*	*Per cent.*	*Mg. per liter.*	*Per cent.*	*Mg. per liter.*
Alkalies..............	15.23	0.391	12.87	0.314	12.48	0.327	13.47	0.403	21.32	0.365
Earths..............	34.77	.893	37.13	.906	37.52	.983	36.53	1.093	28.68	.491
Strong acids..........	5.10	.131	7.58	.185	10.19	.267	7.69	.230	14.08	.241
Weak acids..........	44.90	1.153	42.42	1.035	39.81	1.043	42.31	1.266	35.92	.615
Concentration value..........	100.0	2.568	100.0	2.440	100.0	2.620	100.0	2.992	100.0	1.712
Radicles:	*Formula.*	*Mg. per liter.*	*Formula.*	*Mg. per liter.*	*Formula.*	*Mg. per liter.*	*Formula.*	*Mg. per liter.*	*Formula.*	*Mg. per liter.*
Na..................	13.94	0.358	10.98	0.268	10.34	0.271	11.57	0.346	18.34	0.314
K..................	1.29	.033	1.89	.046	2.14	.056	1.90	.057	2.98	.051
Ca..................	21.81	.560	25.86	.631	26.45	.693	32.68	.978	21.68	.371
Mg..................	12.26	.315	11.23	.274	10.57	.277	2.98	.089	6.36	.109
Fe..................	.70	.018	.04	.001	.50	.013	.87	.026	.64	.011
SO_4..................	3.15	.081	4.01	.098	7.06	.185	4.55	.136	7.89	.135
Cl..................	1.60	.041	2.91	.071	2.71	.071	2.67	.080	5.43	.093
NO_3..................	.35	.009	.66	.016	.42	.011	.47	.014	.76	.013
HCO_3..................	44.90	1.153	42.42	1.035	39.81	1.043	42.31	1.266	35.92	.615
Concentration value..........	100.0	2.568	100.0	2.440	100.0	2.620	100.0	2.992	100.0	1.712
Base analyses.	*Parts per million.*		*Parts per million.*		*Parts per million.*		*Parts per million.*		*Parts per million.*	
Radicles:										
Sodium (Na)..........	8.1		6.4		6.3		8.2		7.3	
Potassium (K).......	1.4		1.9		2.2		2.4		2.0	
Calcium (Ca)..........	11.0		13.0		14.0		20.0		7.6	
Magnesium (Mg)......	3.6		3.7		3.5		1.5		1.5	
Iron (Fe)..........	.5		.02		.37		.75		.33	
Sulphate (SO_4)........	4.1		4.5		8.8		6.3		6.4	
Chloride (Cl)..........	1.6		2.3		2.4		2.6		3.2	
Nitrate (NO_3)........	.56		1.0		.7		.9		.74	
Bicarbonate (HCO_3).	71.0		62.0		62.0		76.0		37.0	
Colloids:										
Silica (SiO_2)..........	29.0		15.0		16.0		23.0		14.0	
Total dissolved solids..........	103.0		76.0		89.0		101.0		59.0	
Number of composites....	12.0		4.0		14.0		14.0		.15	
Dates..................	May 3-Oct. 28, 1907.		Sept. 8-Oct. 17, 1907.		May 5-Nov. 1, 1907.		May 14-Oct. 24, 1907.		May 10-Oct. 19, 1907.	

During the period of the investigation the waters in general were soft and all were characterized by primary alkalinity, by which their softness is maintained. It is true that they contain dissolved mineral substances in small quantities, but the carbonates of the alkalies are perceptibly in excess of the amounts necessary to precipitate the other bases, so that permanent hardness is impossible. Here, then, is a large section of the country favored with running waters whose incrusting constituents can not form hard scale in boilers and whose alkalies are sufficiently in excess to keep them soft. An idea of the excessive alkalinity of these waters can be obtained by expressing their primary alkalinity in terms of sodium carbonate, as was done in considering the waters of Lake Champlain (pp. 9–10). An estimate made in this way shows that the quantity of sodium, reckoned as sodium carbonate—that is, that quantity of sodium in excess of all that can be regarded as equivalent to the sulphates, chlorides, and nitrates annually discharged by the rivers within the area extending from the James to and including the Pearl—is enormous. The calculated quantity of sodium carbonate annually discharged from this area into the Atlantic Ocean and Gulf of Mexico is no less than 2,693,000 tons.

The quantity of alkaline material conveyed by these rivers to the sea is very large compared with the quantity produced commercially. In 1904, for example, 63 establishments in the United States produced 734,209 tons of sodas of all kinds, namely, sodium carbonate, sodium bicarbonate, caustic soda, and sal soda; and 11,511 tons of soda were imported, a total of 754,720 tons, valued at $13,579,080.

RELATION OF WATER PROPERTIES TO GEOLOGIC FORMATIONS.

The result of a mineral analysis of the water of a river may serve as an index of the character of the geologic formations in its drainage basin, if the analyses are expressed, not in amounts of the radicles found in the water, but in terms showing the properties acquired by the water as it passes over or through the rocks.

The waters of Dan, Roanoke, James, and Shenandoah rivers, all originating among the Appalachian Mountains of western Virginia, develop markedly different qualities, as shown by the complete analyses given in Tables 1 and 2. The reaction properties of these waters, as deduced from analyses made of samples collected at points many miles distant from the sources of the rivers, are stated in percentage degrees in the following table:

Reaction properties of waters of Dan, Roanoke, James, and Shenandoah rivers.

	Dan.	Roanoke.	James.	Shenandoah.
Primary salinity	24.2	15.1	18.3	10.5
Secondary salinity	.0	.0	.0	.2
Primary alkalinity	15.3	8.7	4.7	.0
Secondary alkalinity	60.5	76.2	77.0	89.3
	100.0	100.0	100.0	100.0

These figures show a progressive decline northward in the proportion of primary alkalinity, that is, permanent alkalinity, or such alkalinity as would be caused by alkaline carbonates and alkaline bicarbonates (Na_2CO_3 and $NaHCO_3$), and in the water of Shenandoah River this property is entirely wanting. Equally striking is the progressive advance in secondary alkalinity—that is, the property caused by alkaline earth bicarbonates, $CaH_2(CO_3)_2$ and $MgH_2(CO_3)_2$. This property coincides with temporary hardness.

Primary salinity—that is, salinity caused by the sulphates and chlorides of the alkalies—is also a conspicuous property of all these waters, ranging between 10 and 24 per cent of the total properties represented. The prominence of primary salinity among the properties of all these waters and its capacity for independent variation suggest that the cause of the progressive variations in the proportions of the two kinds of alkalinity may be found in the chemical nature of the rocks.

All these rivers, except the Dan, rise in the Appalachian Valley, between the Blue Ridge and the Alleghenies, and start with waters probably of the same general character. The headwaters of the Dan are not strictly within the Appalachian Valley, for the river rises on the eastern slope of the Blue Ridge. It flows eastward in a drainage basin comprising 2,700 square miles, which is practically confined to the granitic area of the Piedmont Plateau. The water was sampled for analysis at South Boston, Va., about 137 miles from the source of the river. The Dan is essentially a primary stream in that its waters derive their soluble substances from decomposed igneous rocks. Its water, like that of many other rivers that flow in areas of crystalline granitic rocks, is high in primary alkalinity.

The Shenandoah, about 120 miles in length, rises in Augusta County, Va., about 25 miles north of Balcony Falls, on James River, flows northeastward in the valley west of the Blue Ridge, and discharges into the Potomac at Harpers Ferry. The properties of its water are directly due to the soluble material received from siliceous limestones and shales. The entire valley is underlain by limestones, the shales outcropping at the base of the mountains. The virtual absence of permanent hardness (0.2 per cent) of the waters near the mouth of the river and the comparatively low primary salinity are characteristic of waters that traverse ancient limestone areas. Shenandoah Valley, lying well south of the region covered by glacial drift, occupies a geographical position favorable for observing the character that a river water acquires directly from the local formations. It is to be observed that the hardness of the Shenandoah River water is alkalinity; its alkalinity is hardness. Alkalinity and hardness are coincident in but few river waters.

Roanoke River rises in the Appalachian Valley in Montgomery County, Va., flows eastward about 50 miles, traversing the same limestone formations which are crossed by James River a few miles farther north and in which the Shenandoah remains through its entire course; it then cuts through the Blue Ridge and emerges on the granitic area of the Piedmont Plateau there to continue its eastward journey. The distance from the Blue Ridge to the sampling

FIGURE 1.—Map showing geologic character of the drainage basins of Shenandoah, James, Roanoke, and Dan rivers. The shaded portion represents the area of crystalline rocks; the unshaded portion, sedimentary rocks. Dash lines represent limits of drainage basins.

station at Randolph, Va., is a little less than 100 miles. The reaction properties of the river water at Randolph may be regarded as typical of a river water beginning in sedimentary formations and subsequently modified by the addition of water from a granitic area.

In comparing the properties of this water with the properties of the waters of the adjacent streams, it should be remembered that the Roanoke flows in an area of sedimentary rocks for about one-third of its course and in an area of granitic rocks for about two-thirds of its course. The drainage area of Roanoke River is very unequally divided between the two geologic districts through which it flows. The portion within the limestone area west of the Blue Ridge comprises about 583 square miles, constituting only about one-fifth of the area of its entire basin; the portion on the Piedmont Plateau comprises about 3,080 square miles, or about four-fifths of the entire area from which the water of the Roanoke has acquired its properties.

James River drains an area about equally divided between the Appalachian Valley and the Piedmont Plateau, the upper part, lying west of the Blue Ridge, embracing 3,030 square miles, and the Piedmont district about 3,800 square miles. Moreover, the James receives in the area of sedimentary formations contributions from several rivers of considerable size. Except for a few good analyses of waters in Rockbridge County, Va., made by A. W. White,[1] no information concerning the composition of these mountain streams is available. Three of White's analyses, interpreted according to the plan here adopted, show the general character of the waters received by the James just before it leaves the region of sedimentary rocks.

Analyses of waters flowing into James River.

[Parts per million.]

1. Moore's Spring, North River drainage basin, near Lexington. Described as flowing from pure limestone.
   - Solid residue (estimated) 162
   - Silica (SiO_2) 7.2
2. South River, tributary to North River. Described as flowing along the dividing line between the Cambrian limestones and Cambrian sandstones.
   - Solid residue (estimated) 113
   - Silica (SiO_2) 5.5
3. North River, tributary to James River. Described as coming chiefly from limestones, sandstones, and shales; sampled above junction with South River.
   - Solid residue (estimated) 85
   - Silica (SiO_2) 5.1

Properties of reaction.

	1	2	3
Primary salinity (alkali salinity)	1.84	4.76	4.98
Secondary salinity (permanent hardness)	4.04	7.38	10.14
Secondary alkalinity (temporary hardness)	94.12	87.86	84.88
	100.0	100.0	100.0

[1] Composition of the waters of Rockbridge County, Va.; thesis for Washington and Lee University, 1906.

These analyses afford excellent examples of the character of water from calcareous formations. The small proportion of silica reported as dissolved in the waters of James River valley west of the Blue Ridge is noteworthy, because of its marked contrast with the proportion of silica in the water of the James after the river has acquired primary alkalinity from the crystalline siliceous formations of the Piedmont Plateau.

This consideration of the chemical character of the waters of Dan, Roanoke, James, and Shenandoah rivers indicates that the results of water analyses may hereafter prove to be helpful guides in regional studies of streams.

SILICA IN RIVER WATERS.

RELATION OF SILICA TO PRIMARY ALKALINITY.

A high proportion of silica in the mineral content of surface waters is thought by many observers to be normal only to small streams flowing from crystalline siliceous rocks, and especially to those streams near their sources; that is, if silica is a prominent constituent of the inorganic material dissolved in the water of a large stream, its presence must be attributed to some extraneous cause, such as tropical climatic conditions in the drainage basin or abundance of organic matter in the waters. The particular kind of organic matter that is supposed to facilitate the transportation of silica in water is that commonly known as azo-humic acids. Owing to supposed basic properties acquired by the incorporation of nitrogenous material, these azo-humic acids are assumed to be capable of forming with hydrated silicic acid soluble compounds of unknown character, and thus to assist the water to carry along the silica with the rest of the "invisible load." Since high importance has been attached to these assumed azo-humic acids in other geologic phenomena involving chemical processes, it seems not out of place here to state the circumstances under which the term azo-humic acids was introduced to chemical literature.

A report had been read before the French Academy of Sciences of certain elaborate experiments made by Friedel and Ladenburg[1] involving the synthesis of a compound of silicon analogous to propionic acid. To that report Paul Thénard[2] offered remarks, in the course of which he alluded to some observations made by himself on the solution of silica in company with soil acids. He suggested that the solution of the silica might be due to nitrogen in the organic substances, but he cautiously refrained from making a definite statement concerning the nature of the products, merely promising to report in detail the results of subsequent experiments. So far as can be learned the promise was not fulfilled.

[1] C. Friedel and A. Ladenburg, Sur l'acide silico-propionique: Compt. Rend., vol. 20, 1870, p. 1407.
[2] P. Thénard, Observations sur le mémoire de M. Friedel: Idem, p. 1412.

The solubility of humic substances in water alone and in alkaline solutions was observed as long ago as 1826. Sprengel[1] was the first to recognize in these products of the soil a new class of substances, and his account of humus acid and its salts contains valuable information concerning the chemistry of these colloidal substances.

Directly bearing on the solubility of silicic acid in solutions of the humic substances is Sprengel's observation that silicic acid is precipitated in gelatinous form if solutions of this kind of organic material are added to a solution of potassium silicate. In view of these early observations by Sprengel concerning the action of humic solutions on silicates, and since Thénard himself seems to have considered as premature his announcement of the possible existence of azo-humic acids, it is unnecessary now to consider those vague substances as factors in the solution and portage of silica in river waters.

The solvent action of alkaline carbonates and hydroxides on silica has long been known. Hydrated silicic acid is easily attacked and dissolved, even by dilute solutions of sodium carbonate, and dilute sodium carbonate is the reagent commonly used in the laboratory to separate silicic acid from quartz and refractory silicates. Unless precaution is taken against using an unduly strong solution of the alkaline carbonate, appreciable amounts of quartz are dissolved with the silicic acid and the separation of silicic acid from quartz is frustrated. Quartz is attacked and dissolved by prolonged digestion in even dilute alkaline carbonate solutions.[2]

SILICA IN THE WATERS OF THE PIEDMONT PLATEAU AND COASTAL PLAIN OF THE GULF OF MEXICO.

As silica contributes largely to the weight of the inorganic substances dissolved in the surface waters of the Piedmont Plateau and Coastal Plain area of the Southern States east of the Mississippi, the analyses of the waters of the rivers of this region afford exceptionally favorable data for a comparative study of the proportional amounts of silica with respect to primary alkalinity—a property common to all the waters during the period of the investigation.

The waters of the rivers fall naturally into three groups, according to the geology of the drainage basins:

Group 1. Waters of streams coming from regions of sedimentary rocks and afterward traversing areas of crystalline rocks.

Group 2. Waters of streams practically confined to areas of crystalline rocks.

Group 3. Waters of streams practically confined to areas of sedimentary rocks and alluvial sands and clays.

[1] Sprengel, C., Ueber Pflanzenhumus, Humussäure und humussaure Salze: Archiv für die gesammte Naturlehre (K. W. G. Kastner), Nürnberg, Band 8, 1826, p. 126-220.

[2] Lunge and Millberg, Zeitschrift für angewandte Chemie, 1897, pp. 390 and 425.

Primary alkalinity and silica in Piedmont Plateau and Gulf Coastal Plain waters.

	Distance from source to sampling station.	Primary alkalinity.	SiO_2 in inorganic substances.
	Miles.	*Per cent.*	*Per cent.*
Group 1:			
James	276	4.7	22.0
Roanoke	162	8.7	28.3
Group 2:			
Dan	137	15.3	38.0
Neuse	72	15.7	37.8
Pedee	225	25.0	38.8
Wateree	216	23.4	38.7
Savannah	168	18.5	31.2
Oconee	176	15.2	24.3
Ocmulgee	62	16.4	32.8
Group 3:			
Alabama	447	10.5	19.2
Cahaba	17	4.8	18.9
Tombigbee	192	11.6	22.3
Pearl	120	14.5	23.0

The acquisition of primary alkalinity by James, Roanoke, and Dan rivers has already been considered in discussing their environment. Equally striking is the proportional increase of silica in the inorganic material contained in their waters. The advance and decline of silica concomitant with the rise and fall in primary alkalinity in all the waters of the Atlantic coast rivers point to a continuance of the correlation of silica with the primary alkalinity of the river waters, just as silica is associated with the alkalies at the beginning. Although subject to various disturbing influences, the mixed waters of the Gulf Coastal Plain rivers show a similar relation between silica and primary alkalinity. A high proportion of silica in the mineral content of these river waters is easily accounted for, because the acidic radicles of the alkaline carbonates, always present in waters of this character, tend constantly to form the sparingly soluble carbonates of the other positive radicles of the solutes, while the soluble bases of the alkalies from the hydrolyzed alkaline carbonates produce alkaline solutions naturally favorable to the retention of dissolved silica.

OTHER RIVERS DRAINING AREAS OF CRYSTALLINE ROCKS.

OTTAWA RIVER.

The Ottawa is the largest tributary of the St. Lawrence. It rises in latitude 47° 53′ north, longitude 75° 35′ west, and discharges into St. Lawrence River near Montreal. It is 730 miles long and drains an area comprising more than 56,000 square miles. According to R. A. Daly, geologist of the International Boundary Commission, the Ottawa basin is larger than any other river basin known to be underlain by pre-Cambrian formations.[1]

[1] Daly, R. A., First calcareous fossils and the evolution of the limestones: Bull. Geol. Soc. America, vol. 20, 1909, pp. 153–170.

The composition of the water of Ottawa River at high stages has been recently determined by Frank T. Shutt and A. Gordon Spencer.[1] The water was collected in July, 1907, from the main stream above Chaudière Falls.

The interpretation of an analysis of Ottawa River water made by T. Sterry Hunt at a much earlier date shows that before the snows begin to melt the proportion of primary alkalinity to the other properties of the water is much higher than it appears to be during the summer floods. The water for Hunt's analysis was collected in March, 1854, at St. Anne's Lock, near Montreal.[2]

These analyses are interpreted in the following table:

Character of Ottawa River water interpreted from analyses.

	Analysis by Shutt and Spencer.	Analysis by Hunt.	Average.
Properties:	*Per cent.*	*Per cent.*	*Per cent.*
Primary salinity	14.7	8.3	11.5
Primary alkalinity	1.8	9.8	5.8
Secondary alkalinity	83.5	81.9	82.7
	100.0	100.0	100.0
Reacting values of groups:			
Alkalies	8.23	9.03	8.63
Earths	41.77	40.97	41.37
Strong acids	7.35	4.13	5.74
Weak acids	42.65	45.87	44.26
	100.0	100.0	100.0
Reacting values of radicles:			
r Na	6.77	6.67	....
r K	1.46	2.36	....
r Ca	28.04	32.33	....
r Mg	13.73	8.64	....
r CO_3	41.88	45.77	....
r PO_4	.77	....	....
r SO_4	6.0	2.62	....
r Cl	1.35	1.51	....
	100.0	100.0	....
	Mg. per liter.	Mg. per liter.	
Total dissolved	35.1	60.0	....
Colloids:			....
SiO_2	7.1	21.0	....
Al_2O_3	.5		....
Fe_2O_3	.7	....	....
Concentration value	1.034	1.528	....

Attention is called to the high proportion of silica in the mineral content of the water at the time of Hunt's analysis and also to the striking differences in the chemical character of the solutions with respect to the proportions of properties on the two occasions when the water of Ottawa River was investigated.

[1] Trans. Royal Soc. Canada, 3d series, vol. 2, 1909, p. 175.

[2] Hunt, T. S., Canada Geol. Survey Rept., 1863, p. 565.

MAHANUDDY RIVER, INDIA, AND URUGUAY RIVER, BRAZIL.

Mahanuddy River, of India, is selected to illustrate the chemical character of a river water draining a sparsely settled area. According to Edward Nicholson, the geologic formations in its drainage basin are made up chiefly of trap, basalt, and gneiss, and the soils formed by the decomposition of those rocks. The river is about 500 miles long, and empties into the Bay of Bengal. The drainage basin of Mahanuddy River lies wholly within the Tropics. The analysis interpreted was made by Nicholson [1] on a sample collected at Cuttack, India, about 60 miles above the mouth of the river.

Uruguay River rises in the mountains of Santa Catharina in southern Brazil, flows first westward and then southward, and empties into the La Plata near Buenos Aires. The Uruguay is about 1,000 miles long. Its water is said to be clear and free from sediment, except during seasons of flood. The high primary alkalinity of the water and the high proportion of silica in the dissolved inorganic material are noteworthy features of this great stream of the South Temperate Zone. The analysis selected for interpretation was made by Kyle,[2] who was for many years water expert in Argentina.

The character of Mahanuddy and Uruguay rivers, as interpreted from the analyses, is shown in the following table:

Character of Mahanuddy and Uruguay rivers.

	Mahanuddy (Nicholson, analyst).	Uruguay (Kyle, analyst).
Properties:		
Primary salinity	13.7	18.2
Primary alkalinity	6.6	6.9
Secondary alkalinity	79.7	74.9
	100.0	100.0
Reacting values of groups:		
Alkalies	10.16	12.54
Earths	39.84	37.46
Strong acids	6.85	9.08
Weak acids	43.15	40.92
	100.0	100.0
Reacting values of radicles:		
r Na	8.69	8.57
r K	1.47	3.97
r Ca	26.54	25.32
r Mg	13.02	12.14
r Fe	.28	....
r CO_3	42.41	40.92
r PO_4	.74	....
r SO_4	.78	3.84
r Cl	1.97	.77
r NO_3	4.10	4.47
	100.0	100.0

[1] Jour. Chem. Soc., 1873, p. 229.

[2] Kyle, J. J. J., Chem. News, vol. 38, 1878, p. 28.

Character of Mahanuddy and Uruguay rivers—Continued.

	Mg. per liter.	Mg. per liter.
Total dissolved	86.0	39.8
Colloids:		
SiO_2	27.8	18.5
Concentration value	2.438	0.782

Mr. Kyle's official duties in connection with choosing a suitable water supply for Buenos Aires afforded him unusual opportunity to learn the character and quality of many rivers in the surrounding territory. A subsequent report by Kyle shows that primary alkalinity is not confined to Uruguay River but is characteristic of many rivers in the same drainage area.

Kyle's description of the appearance of Uruguay River, of its purity, and of the siliceous character of its water deserves to be quoted:

> The water of the river Uruguay is in some respects very remarkable. It is probably one of the purest river waters in the world, containing rather less than 4 parts of solid matter per 100,000. It is almost free from chlorides; the determination of chlorine, made with every possible care, gave rather less than one-fourth of a milligram per liter, and this, be it remembered, at a distance of say 500 miles from its source.
>
> Still more noteworthy, in my opinion, is the fact that about 46 per cent of the total solid matter consists of soluble silica, not suspended as in the other two rivers. A small proportion exists probably as alkaline silicate, but the greater part is undoubtedly present as hydrated silicic acid. In this circumstance may be found an explanation of the petrifying properties attributed to the water of the Uruguay. On one occasion a cart wheel was fished up from its bed completely converted into stone. A considerable export trade in agates is carried on by the inhabitants on the Uruguayan shores of this great river, and the stones from the Uruguay are, I believe, those most esteemed by European lapidaries. The free silicic acid dissolved by this river among the mountains of Santa Catharina, in Brazil, is probably the raw material out of which are elaborated the agate mortars so invaluable to every analytical chemist.

PERSISTENCE OF SILICA IN RIVER WATERS.

The percentage values of the primary and secondary alkalinity of the Ottawa, Mahanuddy, and Uruguay River waters as obtained from the character formulas are repeated here for comparison.

Alkalinity of Ottawa, Mahanuddy, and Uruguay rivers.

	Ottawa (average).	Mahanuddy.	Uruguay.
Primary alkalinity	5.8	6.6	6.9
Secondary alkalinity	82.7	79.7	74.9

The percentage of silica in the dissolved inorganic material is, for Ottawa River, 29; for Mahanuddy River, 32; and for Uruguay River, 46.

Kyle's results show that the high proportion of silica in the inorganic material of Uruguay River can not be correlated with dissolved organic matter but may, on the contrary, be due, in part at least, to the absence of organic matter. The Uruguay, in latitude 27° to 36° south, occupies in the Southern Hemisphere a position closely corresponding to that of the Piedmont Plateau and Coastal Plain area, between latitudes 30° and 38° north. Mahanuddy River is tropical; the Ottawa flows in the far north. The waters of all these rivers are primary-alkaline, and, irrespective of climate, all of them show a tendency favorable to the retention of silica. Their story corroborates the story told by the rivers of our own land. The high proportion of silica, moreover, in the mineral content of the waters of these three great rivers, draining granitic areas in widely separated parts of the earth, indicates that as a prominent constituent of the dissolved material, silica in river waters is not necessarily confined to the waters near the sources of the streams. On the contrary, the evidence tends to show that silica may constitute a large part of the material in the water of rivers at remote distances from their sources, if the conditions are such as to maintain the primary alkalinity of their waters.

The actual state of silica in highly dilute solution may not be perfectly understood and these observations do not bear directly on its physical condition, but it is hoped that they will show the propriety of interpreting mineral analyses of water according to modern chemical principles.

THE WATER OF MISSISSIPPI RIVER.

The interpretation of a series of analyses of the water of Mississippi River made by chemists of the United States Geological Survey reveals the changes in the character of the water of a great river at different points. As shown in Table 4, the water of the Mississippi at Minneapolis is very simple in character, being distinguished only by secondary alkalinity, primary salinity, and very low secondary salinity or permanent hardness. In these qualities the water of the Mississippi resembles the water of the Shenandoah at its mouth. At Moline, Ill., permanent hardness appears definitely among the properties of the Mississippi water, although it occupies a very subordinate position. It should be observed that the proportion of primary salinity in the water of the upper Mississippi remains practically constant for the entire distance between Minneapolis, Minn., and Quincy, Ill., thus constituting an important feature of the water of this part of the river. At Chester, Ill., the character of the water appears to be greatly changed, for the analyses indicate that the proportion of primary salinity is much increased and the proportion of permanent hardness—that is, secondary salinity—is more than doubled.

		Missouri at mouth.		
	) a	At Ruegg, Mo. a b		
Properties.		*Per cent.*		*Properties.*
Primary salinity....		27.8		Primary salinity.
Secondary salinity.		18.8		Secondary salinity.
Secondary alkalinit;		53.4		Secondary alkalinity.
		100.0		
Reacting valu				*Reacting values.*
Groups:	*ter.*	*Per cent.*	*Mg. per liter.*	Groups:
Alkalies.......	10	13.89	1.517	Alkalies.
Earths.........	70	36.11	3.941	Earths.
Strong acids...	16	23.30	2.544	Strong acids.
Weak acids....	54	26.70	2.914	Weak acids.
Concentratio	20	100.0	10.916	Concentration value.
Radicles:	*ter.*	*Formula.*	*Mg. per liter.*	Radicles:
r Na..........	10	12.37	1.351	r Na.
r K..........		1.52	.166	r K.
r Ca..........	3	23.84	2.600	r Ca.
r Mg..........	17	12.11	1.323	r Mg.
r Fe..........		.16	.018	r Fe.
r SO_4..........	2	19.80	2.162	r SO_4.
r Cl..........	3	3.08	.336	r Cl.
r NO_3..........	1	.42	.046	r NO_3.
r HCO_3..........	4	26.70	2.914	r HCO_3.
r CO_3..........		.0	.0	r CO_3.
Concentratio	0	100.0	10.916	Concentration value.
Base analyse				*Base analyses.*
Radicles:		*Parts per million.*		Radicles:
Sodium (Na)...		31.0		Sodium (Na).
Potassium (K).		6.5		Potassium (K).
Calcium (Ca)..		52.0		Calcium (Ca).
Magnesium (M		16.0		Magnesium (Mg).
Iron (Fe)......		.51		Iron (Fe).
Sulphate (SO_4		104.0		Sulphate (SO_4).
Chloride (Cl)..		12.0		Chloride (Cl).
Nitrate (NO_3).		2.9		Nitrate (NO_3).
Bicarbonate (H		178.0		Bicarbonate (HCO_3).
Carbonate (CO		.0		Carbonate (CO_3).
Colloids:				Colloids:
Silica (SiO_2)..		29.0		Silica (SiO_2).
Alumina (Al_2O		....		Alumina (Al_2O_3).
Iron (Fe_2O_3)...		....		Iron (Fe_2O_3).
Total dissolv		346.0		Total dissolved solids.
Number of compos		36		Number of composites.
Dates..........		Sept. 27, 1906–Oct. 6, 1907.		Dates.

a Averages of
b Reported in 7 daily collections.
c Reported w
Supply Paper

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The proportional variation that has taken place in the properties of the river water between Quincy and Chester is the same in kind as the change commonly observed in the properties of a chemical reagent if the proportions of the salts dissolved in it are changed. The principal cause of the change in the proportions of properties observed in the water of the Mississippi at Chester is the highly saline water poured by the Missouri into the Mississippi at a point between Quincy and Chester. From Chester to New Orleans the river water appears to undergo no permanent change in general character. In the water at Memphis the analyses indicate temporary reduction in secondary salinity, probably due in large measure to water brought in by Ohio River. Additional contributions of saline waters from the West, received through Arkansas and Red rivers, suffice to maintain in the water of the lower Mississippi that high proportion of salinity first derived midway in its course from Missouri River.

The changes in the character of the waters of the upper and lower Mississippi show the manner in which salinity may be developed in the water of a river whose drainage basin contains large areas of sedimentary rocks.

THE WATER OF THE GREAT LAKES AND ST. LAWRENCE RIVER.

The changes in the character of the water of the St. Lawrence River system occur in somewhat different order from that observed in the course of the Mississippi, and may be traced through the Great Lakes by interpretations of recent analyses by Dole and Roberts.[1] As Lake Superior occupies a higher and more westerly position than the other lakes, it will be considered first.

The interpretation presented in Table 5 indicates that the water of Lake Superior—the largest body of fresh water on the globe—is distinguished by primary alkalinity. The water of Lake Michigan is very different from that of Lake Superior, as the samples show properties characteristic of a water coming from a region of sedimentary rocks, and a distinct resemblance is shown between the water of Lake Michigan and that in the lower part of Lake Huron.

At Buffalo, N. Y., the total primary and secondary salinity of the water of Lake Erie shows an increase of 9 per cent over the proportion of the same properties in the water of Lake Huron. That this conspicuous change in the character of the water of the Great Lakes is caused by local conditions may be inferred from the fact that no further change of properties in the same direction is observable in the water at Ogdensburg, N. Y., even after its long journey through Lake Ontario. The character formula of Lake Erie water discloses at once the fact that the remarkable increment in the proportion of salinity in the lake water is caused by chlorides and sulphates and suggests

[1] Water-Supply Paper U. S. Geol. Survey No. 236.

the advent of brines, known to abound among the rocks in the drainage area of Lake Erie. One of the most important streams draining this area is the Maumee, whose water, where it enters the upper end of Lake Erie, closely approaches a brine in character. Since the character formula is distinctively a rational expression, the reacting ratios of the radicles in the formula can be obtained directly from their percentage values. In the formula it will thus be seen that the value of the chlorides exceeds the total value of the alkalies. This relation is exceptional in river waters and may be charged directly to the waste brines that flow into Maumee River from the numerous oil wells of the district. The excess of chlorides of the alkaline earths over alkaline chlorides is not peculiar to the brines of Ohio. In the salt water already mentioned as occurring at Highland, Ill., a similar condition may be seen. In localities where salt is produced as a commercial article from Ohio brines, the excess of alkaline earth chlorides is sufficient to warrant the separate manufacture of calcium chloride, and this compound is reported to be a very profitable by-product of the salt industry.

From the values in the character formula the relative reacting values of the different radicles may be traced. The ratios of the reacting values of sodium and chlorine in the Great Lakes, chlorine being 1, are shown below:

Sodium in Great Lakes.

Lake Superior	4.0
Lake Michigan	2.7
Lake Huron	2.4
Lake Erie	1.2
Lake Ontario	1.3

The ratio for the water of Lake Ontario is taken from the analysis of the St. Lawrence River water at Ogdensburg, N. Y.

In the Mississippi River water a similar progressive advance of chlorine on sodium is also observed. The ratios are shown below, chlorine being unity.

Sodium in Mississippi River.

Minneapolis	8.8
Moline	4.0
Quincy	3.7
Chester	3.2
Memphis	2.4
New Orleans	1.8

The progressive advance of chlorine on sodium in the water of the Mississippi and of the Lakes shows lines along which flowing water develops salinity as it traverses sedimentary rocks.

As the water from Lake Ontario enters the channel of St. Lawrence River it becomes subject to conditions prevailing in a region of ancient crystalline rocks. The change in character resulting from change

	…iter.	St. Lawrence River, Pointe des Cascades, opposite Vaudreuil.[a]	
Properties.		*Per cent.*	
Primary salinity.		9.6	
Secondary salinity.		.0	
Primary alkalinity.		.7	
Secondary alkalinity.		89.7	
		100.0	
Reacting values.			
Groups:	…iter.	*Per cent.*	*Mg. per liter.*
Alkalies.	12	5.16	0.254
Earths.	26	44.84	2.209
Strong acids.	38	4.81	.237
Weak acids.	00	45.19	2.226
Concentration value.	76	100.0	4.926
Radicles:	…iter.	*Formula.*	*Mg. per liter.*
r Na.	12	4.53	0.223
r K.		.63	.031
r Ca.	45	32.52	1.602
r Mg.	81	12.32	.607
r Fe.	...	....	....
r SO_4.	33	3.51	.173
r Cl.	05	1.30	.064
r NO_3.	...	....	....
r HCO_3.	...	....	....
r CO_3.	00	45.19	2.226
Concentration value.	76	100.0	4.926
Base analyses.			
Radicles:		*Parts per million.*	
Sodium (Na).		5.1	
Potassium (K).		1.2	
Calcium (Ca).		32.0	
Magnesium (Mg).		7.2	
Iron (Fe).	...	....	
Sulphate (SO_4).		8.3	
Chloride (Cl).		2.3	
Nitrate (NO_3).	...	....	
Bicarbonate (HCO_3)	...	....	
Carbonate (CO_3).		67.0	
Colloids:			
Silica (SiO_2).		37.0	
Total dissolved solids.		160.1	
Number of analyses.	...	....	
Collections monthly.	4,	Collected Mar., 1854.	

[a] Dol, Geol. Survey, Canada, Rept. for 1863, p. 565.

in environment appears in the interpretation of analyses of the water at Ogdensburg, N. Y. (Table 5). Between Buffalo, on Lake Erie, and Ogdensburg no appreciable change appears to have occurred in the amount of soluble material contained in the water, but a decided reduction is evident in the concentration value of the solution. The change in this value, coincident with a change in the proportions of the properties of the solution, while the weight of the dissolved salts remains practically constant, should not be overlooked. That this incipient reversion from salinity to alkalinity is due to environment is manifest. It is only necessary to recall the fact that directly below the point at which samples of the St. Lawrence water were collected Oswegatchie River is adding primary-alkaline water, brought from the Adirondacks, to reduce the secondary salinity of the St. Lawrence waters, which reached its maximum at Buffalo.

For judging the chemical character of the St. Lawrence River water below Ogdensburg the available data are very limited. An analysis made in 1884[1] of the river water collected on the south side of the river opposite Montreal shows a still further reduction in the proportion of secondary salinity, and is in perfect accord with the inference that might follow the consideration of what is known to be going on at the upper end of the St. Lawrence River channel.

Even more striking is a very early analysis of the river water made by T. Sterry Hunt. The water was collected in the main St. Lawrence just above the most westerly outlet of the Ottawa, in the same month and year in which the sample was taken for the analysis of the Ottawa River water that has already been considered. The complete reversion of secondary salinity to alkalinity indicated at this point should not be taken too seriously, for a temporary eddying of the waters may have caused admixture of the river water with a primary water. At all events the tendency of the St. Lawrence water to revert to a primary-alkaline water is abundantly shown. Below the city of Montreal the Ottawa enters the St. Lawrence by two additional channels, and about 45 miles below Montreal the Richelieu is adding its alkaline waters brought from Lake Champlain. With the data at hand it is impossible to state with certainty how far the work of restoration brings back the character of the water of the St. Lawrence to the character of the water of Lake Superior. In the regional study of waters there is much to be done, and great profit is to be expected from work in this field.

CONCLUSION.

In this preliminary consideration of water analyses sufficient ground has been covered to justify the conclusion that natural water may be definitely characterized if the salts dissolved in it are recognized not as a load but as a chemical system of balanced values.

[1] Analysis by Norman Tate; published by T. Mellard Reade in Evolution of earth structure, 190'

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